Studies on a serious outbreak of Aspidiotus destructor rigidus in the coconut-palms of Sangi (North Celebes).

by

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(with 9 plates.)

1. Introduction.

Aspidiotus destructor Sign. is known as one of the worst pests of the coconut-palm. The insect is repeatedly mentioned in literature (— in the Review of applied Entomology 1913—1940 about 300 times —) but hitherto only few data have been published on its biology. A notable exception to this is Taylor's article (1935) on : "The campaign against *Aspidiotus destructor* Sign. in Fiji". Taylor visited Java in the latter half of 1926 and made a detailed study of the parasites of *Aspidiotus destructor* in that island with the intention to import the most efficient ones into Fiji, where *Aspidiotus destructor* caused considerable damage at that time.

Until 1925 this scale-insect did little or no damage in the Dutch East Indies. In the annual reports on pests and diseases of cultivated plants in the Netherlands Indies, published by the Institute of Plant-diseases at Buitenzorg (Java) since 1913, damage by *Aspidiotus destructor* is nowhere mentioned before 1925. The more remarkable was a serious outbreak in the coconut-palms of Sangi, an island half-way between Celebes and Mindanao (Philippines). Starting in the middle of 1925 at Taroena*) (the chief-place and seat of the local government of the Sangi- and Talaud-islands) this outbreak came to a close in the first months of 1928, when nearly 400.000 coconut-palms were attacked and without fruits ; about 30.000 of these palms were killed. The insect, which was responsible for those ravages, differs in its biology considerably from the typical *Aspidiotus destructor* and is described as a new subspecies *rigidus* (see § 4).

The present writer arrived in June 1927 in the Dutch East Indies and was especially charged by the above-mentioned Institute with the study of this and other coconut-pests in Celebes and the Moluccas. In 1927 and 1928 he spent a large part of his time on Sangi to study the *Aspidiotus*-outbreak and paid several visits to that island from 1929 to 1933.

The following article is an extract from a detailed report in Dutch, which was completed in 1933 after the writer's return to Holland, but never published on account of several circumstances. A few additions have been made with regard to literature and data of later years.

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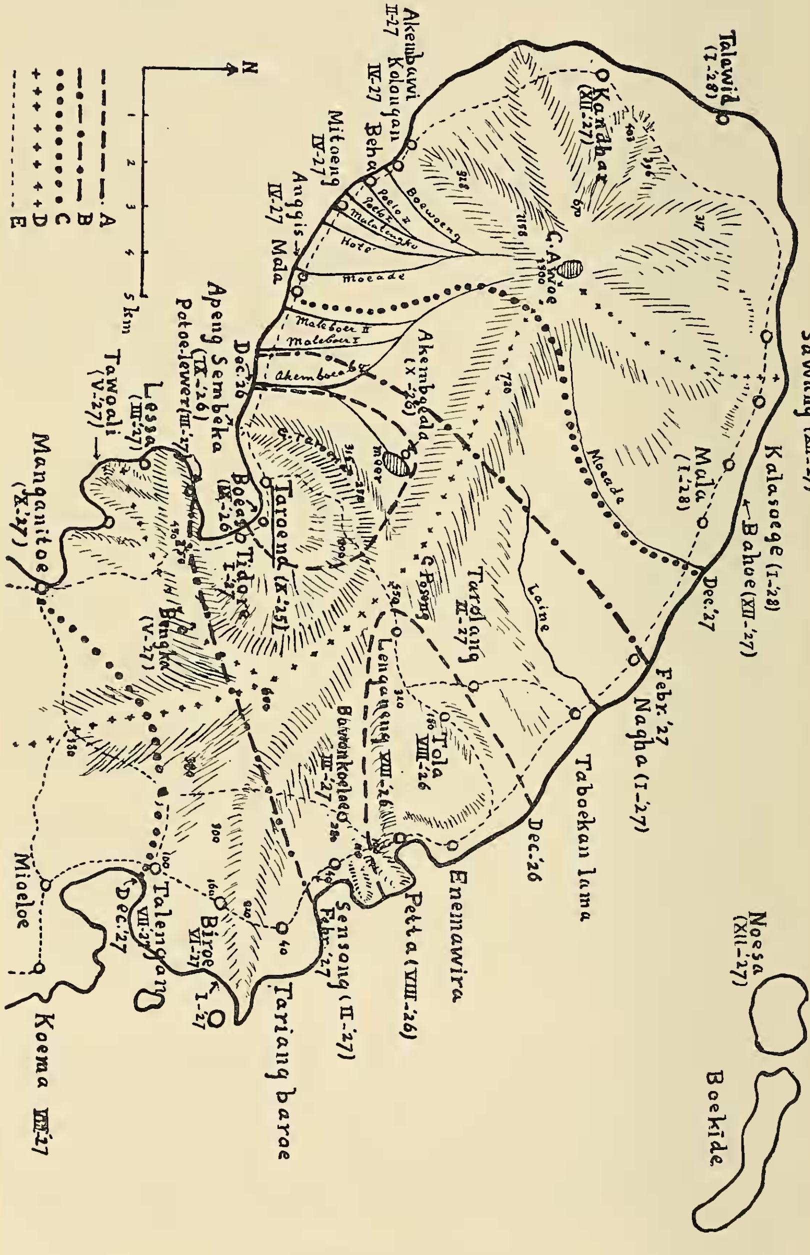
* In this and other geographical names the Dutch spelling is used ; oe is pronounced like the *u* of full.

PLATE I.



For explanation see p. 121.

PLATE II.

For explanation see p. 121.

Sangi (Pl. I and II) is a mountainous island of volcanic origin, with an area of c. 500 km^2 and a population of about 90.000 (census 1930) whose principal means of subsistence is coconut-cultivation. The whole northern part of the island is occupied by an active volcano Mt Awoe (area nearly 135 km^2) which erupted in the 19th century in 1812, 1856 and 1892. During the last eruption Sangi was covered by an ash-layer of 6—15 cm thickness (Kemmerling 1923). The annual rainfall is about 4000 millimetres (157.5 inches), the number of rainy days 200. The average monthly rainfall at Taroena for the years 1896—1928 was: Jan. 477, Febr. 391, March 343, Apr. 328, May 323, June 315, July 290, Aug. 214, Sept. 207, Oct. 243, Nov. 381, Dec. 482, total 3994 millimetres.

The most productive coconut-soils are found at the foot of Mt Awoe. The coconut-palms are planted all along the coast and upon the slopes (even on slopes of 30—40° declivity) to a height of 300—500 m above sea-level. Above 300 m coconut-cultivation on a commercial scale is no longer profitable according to the experience of native and European planters in North Celebes. The number of coconut-palms is nearly 4.000.000 according to a rough estimate of the native chiefs; there are no European plantations on Sangi. Early authors like Padtbrugge (1677), Valentijn (1724) and Rumphius (1750) mention already the abundance of coconut-palms in this island. Hickson (1889), who visited Sangi in 1885, found all the shores densily planted with coconut-palms and the hills around the Bay of Taroena almost destitute of any other trees, which is still true at the present day. The annual export of copra from the 3 principal harbours, Taroena, Tamako and Petta, is about 13.000 tons (1922—1933 average 13.020 t.)*). The first copra from Taroena was exported in 1877.

2. Origin, spread and decline of the outbreak.

Leefmans (1927) visited Taroena in April 1924 and May 1925 on his way to the Talaud-islands, where he studied the *Sexava*-pest in the coconut-palms. Though he paid special attention to coconut-insects, he saw nothing alarming at Taroena. It is, however, possible that during his last visit a few palms were already attacked by *Aspidiotus*. Mr. J. D. G. van Setten, agricultural officer in North Celebes, reported that in May 1925 he saw in the garden of a house at Taroena about 10 coconut-palms attacked by these scale-insects; bananas growing under those palms were also infested. The rajah, Mr. Chr. Ponto, and some other inhabitants of Taroena have shown me a special coconut-grove (presumably the same which Mr. van Setten saw) as the original focus of the *Aspidiotus*-outbreak. According to observations of European residents and visitors the pest arose in the western part of the village (west of the market-place and govt-office) where this coconut-grove is found.

According to Mr. Ponto, the rajah of the district Taroena, the pest became alarming in Oct. or Nov. 1925; a few hundreds of trees were already attacked. Since that time *Aspidiotus* spread rapidly around Taroena till the spring of 1928, when the outbreak came to an end. The progress of the pest is shown on the map in Pl. I, where the month of invasion of different villages is noted and where the approximate extent of the infested area in Dec. 1926, Febr. 1927 and Dec. 1927 is indicated by special lines (see explanation pl. I). In a letter of the local shipping-agent, dated 31 May 1926, it was stated that the coconut-

*) Including export from the harbour Dagho for 1927—1929.

palms at Taroena were attacked since Sept. 1925 by millions of very small yellow flies (i.e. the males of *Aspidiotus;* the females were considered to be the eggs of these flies) which made the leaves wither and killed the trees; more than 5000 palms were already infested.

In Sept. 1926 Mr. van Setten and the American entomologist Mr. C. E. Pemberton (then staying in North Celebes) paid a visit to Taroena; some 30.000 coconut-trees were already attacked, and thousands had been killed. The infestation was still confined to the immediate neighbourhood of Taroena from Apeng Sembeka to Boeas (Pl. I), judging from the yellow and withered coconut-trees. At that time, however, it crossed the circular hill-ridge around Taroena*) at its lowest point (250 m above sea-level) and invaded the coconut-palms around the lake Akemboeala (Oct. 1926). About August 1926 *Aspidiotus* had crossed this hill-ridge also near Lenganeng (450 m above sea-level) and invaded Petta on the east-coast (see Pl. I). An assistant of Mr. van Setten collected there within a very short time a kerosene-tin full of coconut-leaflets, heavily infested by *Aspidiotus* which as he reported was spreading rapidly around Petta (Dec. 1926). I could examine this material at Buitenzorg; it belonged to the subspecies *rigidus* which is described in § 4. In Febr. 1927 Mr. W. A. K. Serapil, rajah of Taboekan (i.e. the eastern part of Sangi), estimated that already 20.000 coconut-palms were attacked in his district; at 1 Dec. 1927 this number had increased to c. 200.000 according to counts of the village-chiefs; more than 90 per cent of these palms were reported from the sector Nagha—Lenganeng—Bawonkoeloe—Sensong (Pl. I). The *Aspidiotus*-infestation, recognisable by yellow and withered leaves, crept in a close front slowly up the steep slopes behind Taroena, but after having reached the top of the ridge it spread rapidly and sporadically, as by jumps, over the east-side of the island. Petta, at a distance of more than 8 km from Taroena, was invaded half a year earlier than Patoe-lewer, a village which lies 1 km south of Taroena on the opposite side of the bay (Pl. I). This is due to dispersal of *Aspidiotus* by strong western winds, as will be explained further on.

In a southern direction the Taroena-pest followed the coast, it did not cross the hill-ridge on the south-side of the Bay. At the end of the outbreak it had only reached Manganitoe (Pl. I).

In the fertile plain of Anggis, which lies N.W. of Taroena and south of Mt Awoe**), *Aspidiotus* spread in an irregular way, mainly along the foot of the mountain-ridge between Mt Awoe and Mt Posong (Pl. I). In Nov. 1927 only few thousands of palms were attacked there. *Aspidiotus* settled especially along the small rivers that intersect that plain. The same was noticed during the rapid spread in the eastern part of the island, where the scale-insects appeared first in moist valleys and at low places along the coast.

In Dec. 1927 and Jan. 1928 *Aspidiotus* caused also slight damage in the villages north of Mt Awoe. On the east-coast it advanced southward to Saloeran (Febr. 1928). It is very remarkable that the western part of Noesa, at a distance of more than 6 km from the main-island, became also infested by the subspecies *rigidus* in Dec. 1927 (1347 palms attacked). Noesa lies in the direction in which the scale-insects spread rapidly in the beginning of 1927 (Pl. I). After the whole east-coast opposite Noesa was infested, *Aspidiotus* has apparently been blown

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*) According to Kemmerling (1923) this steep hill-ridge is an old crater-wall; Taroena and the Bay of Taroena lay at the bottom of a caldera.

**) According to Kemmerling (1923) this plain, gradually rising from sea-level to about 250 m, consists of two flat cones of volcanic material deposited by the rivers Maleboer and Moeade (see Pl. I); the slope is about 5°.

over to this island. On Sangi too some isolated foci of *rigidus* were found at a distance of 5—6 km from the main infested area, so that it seems likely that the young larvae can be carried by wind over such distances.

In Nov. 1927 it drew my attention that all *Aspidiotus destructor rigidus* on mangosteens and sago-palms in Taroena were dead. In the following month the scale-insects on coconuts and bananas showed also a high mortality, but only in and near Taroena, where the pest had raged since the autumn of 1925. When I left Sangi on 31 Dec. 1927 it was clearly visible from the steamer that the coconut-palms along the coast in and near Taroena had become greener by unfolding one or two new leaves which were not attacked by *Aspidiotus* and very conspicuous among the withered foliage. In Febr. and March 1928 when I visited Sangi again and travelled through the whole infested area, the abnormal death-rate of *Aspidiotus* was still confined to Taroena and its immediate neighbourhood ; it had not progressed further than 2 km from the central part of the village, the original focus of the outbreak. On the whole eastern side of the island nothing of this nature was to be seen. In April 1928, when I was only two days at Taroena, the green zone along the coast had already advanced to the river Akemboeala (Pl. I). When I returned to Sangi at the end of July 1928 the outbreak had come to a standstill in the whole infested area.

As *Aspidiotus* destroys the chlorophyll, causing yellow spots on the leaves, and as the coconut-palm unfolds about every month (at intervals of 23—26 days) a new leaf, the arrest of the outbreak could be easily traced. In most cases there was an almost sudden transition from yellow to green leaves with only one yellow-spotted transitional leaf. Seldom two of such leaves were found, showing that the outbreak came to an end within two months in each locality, as it did at Taroena. From the number of green leaves it was evident that the change had already taken place a few months ago, as was confirmed by the village-chiefs. It is, however, quite certain that in the beginning of March, three months after the change in Taroena, there was no abnormal mortality among the scale-insects on the east-side of the island. The retreat started at Taroena, the original focus, where the pest prevailed longest, and within half a year this retreat spread over the whole infested area, lying north of the line Manganitoe—Talengan (Pl. I). The scale-insects did not die out completely but occurred only in small colonies and sporadically.

A proper revival of the outbreak after the middle of 1928 has not occurred, *Aspidiotus* continued its course in a mild form over the southern part of the island. In April 1930 the whole island was inspected again. At the margins of the infested area *Aspidiotus* showed some activity but only small groups of palms, comprising at the most a few hundreds of trees, were slightly infested. Though the number of yellow-spotted *Aspidiotus*-trees was still near 20.000 according to the reports of the village-chiefs, it is likely that no more than a few thousands did suffer any damage by loss of crop. In the worst case (a plot of 400 palms) a crop-reduction of 60—80 per cent was reported. Along the west-coast the subspecies *rigidus* had now advanced from Manganitoe (invaded Oct. 1927) to Tamako, Dagho, and even to Ngalipaeng, the most southern village, but without doing any damage, so that the inhabitants had not even noticed its presence. Meanwhile it appeared that not only the subspecies *rigidus* but also the parasite *Comperiella unifasciata* Ishii, introduced from Java to combate it, had spread over the whole southern part of Sangi (Saloeran, Ngalipaeng, Dagho, Tamako) and even to the island of Noesa (Cf. Reyne 1947). In 1931 and 1933 there were no complaints about *Aspidiotus*. In 1932 the insect was reported from four villages but in total less than 200 palms were attacked.

Aspidiotus destructor rigidus on Sangi was principally spread by wind, less by mutual contact of the trees. No cases of spread by man have come to my notice, though Taroena is visited on market-days by hundreds of canoes from the southern part of the island, which are generally covered with coconut-leaves when transporting cargo or when drawn up the beach. It is, however, likely that the subspecies *rigidus* was originally introduced into Taroena by the agency of man, presumably by coconut-seedlings or ornamental palms brought from North Celebes. That the scale-insects on Sangi were principally spread by southern and western winds is evident from their progress in the field (Cf Pl. I). Petta and its environment on the east-coast were infested by *Aspidiotus* after strong west-winds ("barat") in the latter half of 1926, as was stated by Mr. Serapil, the rajah residing at that place.

On Sangi occasional strong winds blow from a western direction during the driest months (July-Oct.), when multiplication of *Aspidiotus* is at its highest point; the prevailing wind at that time is from the south. The spread of *Aspidiotus* was most rapid in a N.E. direction *); in Dec. 1927 the insects even reached Noesa at a distance of more than 6 km from the main-island. Spreading by wind was also very conspicuous on the north-coast of the Bay of Manganitoe, where three mountain-ridges project with capes into the sea. On the sides of these ridges which were exposed to the western winds the coconut-palms were withered while on their lee-sides they were still green.

The progress from Taroena was slow in a western and southern direction. The spread along the coast, west of Taroena, was probably in the main by contact; the treeless river-beds near the coast, widened by torrents of volcanic mud ("lahars"), acted distinctly as barriers.

Wind-dispersal of the young crawling larvae of *Aspidiotus* can be easily demonstrated by exposure of glass-plates smeared with tanglefoot (a sticky substance for catching caterpillars etc.). If such plates are placed below heavily infested coconut-palms many males and larvae of *Aspidiotus* are found on the sticky surfaces; there is apparently a constant rain of *Aspidiotus*-larvae falling down from such trees. Glass-plates with a sticky surface of about 100 cm^2 were exposed on a raft in the Bay of Taroena. In experiment No. 1, 50 metres from the shore, 17 males and 11 larvae of *Aspidiotus* were caught in 24 hours (besides a parasite, *Prospaltella*, and 2 Diptera). In experiment No. 2, 500 metres from the shore, 1 male and 10 larvae of *Aspidiotus* were caught in 20 hours (besides a parasite, *Aphytis chrysomphali* Mercet). In experiment No. 3, 500 metres from the shore, 4 males and 7 larvae of *Aspidiotus* were caught in 24 hours. The experiments were made in Dec. 1927, when *Aspidiotus*-larvae were scarce in and near Taroena. During the two last experiments a strong north-wind was blowing; the raft was about 1000 metres from the nearest *Aspidiotus*-palms. If we put the catching surface of a coconut-palm at 50 m^2 (average planting-distance along the coast about 7 metres) one palm would have caught in experiment No. 2 and 3 in 24 hours respectively 60,000 and 35,000 *Aspidiotus*-larvae. The measurements of the youngest larvae are about $0.22 \times 0.14 \times 0.05$ mm, the weight is estimated to be c. 0.001—0.0015 mg.

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*) In the Bali-outbreak (see § 3) *Aspidiotus* spread in about two years from Den Pasar in a north-western direction to Tabanan (c. 16 km) and in a north-eastern direction to Soekawati (c. 10 km) according to reports of the Institute of Plant-diseases at Buitenzorg. I presume that this was due to the prevailing southern winds (March— Dec.).

3. Damage done to the coconut-palms and their recovery.

On the leaves of the coconut-palm *Aspidiotus destructor rigidus* is found almost exclusively on the lower surface, which contains the stomata (c. 175—225 per mm^2). The upper surface, having no stomata, is very dry in comparison to the lower surface, as can be easily shown by means of cobalt-paper as is used for transpiration-experiments. Only under very deep shade and in a very moist atmosphere a few scale-insects are occasionally found on the upper side of the leaf. In heavy attacks the leaf-stems, leaf-stalks, fruits, fruit-stalks and all other green parts of the coconut-tree are invaded by *Aspidiotus*, which feeds only on the green tissues.

On the point where a newly emerged *Aspidiotus*-larva attaches itself to the leaf a yellow spot soon becomes visible, usually before the larva moults to the second stage (i.e. in *rigidus* within 16—18 days). These yellow spots are most conspicuous on the upper surface of the leaves, though the insects have settled on the lower surface. If the scale-insects are numerous, separate yellow spots will coalesce to larger patches, and finally the whole leaf turns yellow. By this yellow colour *Aspidiotus*-attack is easily recognised, even from a distance, and in tall coconut-palms.

A microscopical examination of a leaflet which is partially discoloured by *Aspidiotus*, shows that near the punctures the chloroplasts have either disappeared or turned yellow. The green colour of the chlorophyll remains longest near the lower epidermis and in the neighbourhood of the fibro-vascular bundles which *Aspidiotus* is unable to pierce. In badly attacked leaves the palisade-tissue becomes almost colourless. It seems that the punctures go straight through the cells ; the tips of the mouth-setae are usually found in or near the middle of the lamina ; the upper part of the lamina with the palisade-tissue contains more chlorophyll than the lower part with the spongy tissue. The mouth-setae pierce the epidermis often (in 78 per cent of the punctures examined) through the thin-walled parts adjacent to the guard-cells of the stomata, which are slightly sunken below the surface of the leaf.

It is clear that photosynthesis is strongly reduced by a wholesale destruction of the chlorophyll. On the other hand the loss of water seems to be increased by the presence of *Aspidiotus* as is shown by application of cobalt-paper. Finally the coconut-palm is seriously damaged in its growth and its fruit-production as will be explained below.

When the scale-insects are few in numbers, they generally occupy the lower parts of the coconut-leaflets or pinnae, especially their slightly folded base. This folded base is apparently the most favourable habitat on the coconut-palm ; the leaf-tissue is there thickest and most sappy and offers protection against desiccation and wetting by rain ; the extreme tip of the leaflet is sparingly or not occupied by *Aspidiotus* as it offers no protection and contains less green tissue. If the insects are more numerous they are usually distributed over a number of adjacent leaflets. When this number is not above 10—20 (i.e. 4—8 per cent of the area of one leaf) the yellow leaflets remain alive and do not die prematurely. In these cases the coconut-palm suffers no appreciable damage. If *Aspidiotus* becomes still more numerous it will spread diffusely over the whole leaf. In heavy attacks when all green parts of the palm (except the upper sides of the leaves) are incrustated by *Aspidiotus*, the density of the scale-insects is about 20—30 per cm^2 or 40—60 millions per adult coconut-palm (available leaf-area c. 200 m^2). In this case it is seen that the young larvae pierce the scales of the former generation and also

that they crawl under these scales to find a place for attachment. Larvae that find no place to settle drop from the tree, and may be carried away by the wind to other trees (§ 2).

The first effect of a serious attack of *Aspidiotus* on coconut-palms is, besides yellowing of the leaves, a decrease in crop. The copra-content and the number of nuts diminishes. On Sangi it was observed in trees which became heavily infested within a short time, that nuts which at the time of invasion had reached an age of 9 months could still be harvested for making copra, but with a loss of 25 per cent or more, while younger nuts were wholly lost. The coconut-water becomes tasteless or slightly sour during *Aspidiotus*-attacks ; the palm-cabbage has also an insipid taste ; this is probably due to a loss in sugar-content. In moderate attacks as occur on the north-coast of Celebes (between Kwandang and Biontong), where the coconut-trees are not killed or seriously damaged the loss of copra is usually 25—50 per cent. In the infested area on Sangi practically no nuts were harvested. The production of sago-palms was reduced from about 12 baskets of sago (each 60 katti or about 80 lbs) to 7 baskets according to Mr. Serapil, the rajah of Taboekan, but the infestation of sago-palms was always very slight in comparison to coconut-trees.

A serious attack by *Aspidiotus*, as occurred on Sangi, has also a marked effect on the vegetative growth of the coconut-palm. After the leaves which were first attacked have withered, the new ones that unfold become smaller and smaller, so that the crown assumes the shape of an umbrella (Pl. IV, fig. 1). Only the apex of the new leaves is fully developed ; the leaf-stalk (in healthy trees about 1 m in length) is almost wholly suppressed and the leaflets in the lower part of the blade are densily crowded. The leaf-stalks and leaf-stems of badly infested coconut-trees are much thinner than in healthy ones (Pl. IX, fig. 1). The sclerenchyma around the vascular bundles is imperfecty developed (Pl. IX, fig. 2) and lignification is deficient. In consequence of this the leaf-stem loses its rigidity so that the leaves are strongly bent with their tips pointing to the earth ; sometimes they break by their own weight (Pl. V, fig. 1).

The tissue of the leaf-stem and what is left of the leaf-stalk is so soft that it can be easily cut with a small pocket-knife while in healthy leaves a cutlass is needed. The same applies to the portion of the stem just below the crown. In several cases one could squeeze water out of these parts merely by pressure of the hand. When the coconut-palms were felled the crown often broke off, sometimes it was snapped off by the wind (Pl. III). Finally the crown was reduced to a small tuft of a few short leaves, at the most 7—10 feet long as against 15—20 feet in healthy trees. At last the tree died with 1 or 2 green leaves left or it recovered slowly after the outbreak had passed. Even in vigorous coconut-palms the crown could collapse within half a year after they had been overwhelmed by the scale-insects ; in several cases the palms died within a year after the first attack. It seems that death in full-grown palms was mainly due to drying-up of the terminal bud ; budrot was not observed.

The following table illustrates the effect of *Aspidiotus*-attack on the development of coconut-leaves (a = before the attack, b = after severe damage by *Aspidiotus*).

In 50 adult coconut-palms at Taroena, arbitrarily chosen, the number of leaves varied from 8—21, average 13.2 (in healthy trees 30—40).

The growth in length of the stem was greatly reduced as was evident from the densily crowded leaf-scars ; in some cases the growth in thickness was also impaired resulting in a constriction of the stem. Such

Tree no.	Length of blade	Length of leaf-stalk	Dimensions of leaf-stalk at base of blade	Distance between basal leaflets	Diameter of sclerenchyma bundles
1 a	5.2 m	1.17 m	6 × 3.5 cm	7 cm	0.63 mm
1 b	2.7	0.5	3.7 × 2.2	2.5–3	0.33
2 a	5.0	1 0	10 × 3.7	3.3	0.60
2 b	2.3	0.2	4.7 × 2.2	0.9–1.25	0.30
3 a	4.0	0.8	8 × 3.3	3–4	0.61
3 b	2.0	0	3.8 × 2.2	1.8–2.6	0.38
4 a	3 8	—	6 × 2.6	2.5–4	0.60
4 b	3.0	—	5.6 × 2.4	2.0–3.2	0.41
5 a	4.0	0.85	7 × 3.2	3 3–3 7	0.67
5 b	3.1	0.30	6.2 × 2.8	2–3	0.49

Remarks. No. 1 was a young palm of 3—4 years in which the stem was already visible. No. 2—5 were old palms with a collapsed crown. The figures for the sclerenchyma-bundles are averages for 10 bundles in the centre of the leaf-stalk at the base of the blade (for each bundle the average of the largest and smallest diameter of the elliptic cross-section was chosen).

constrictions are also caused by other unfavourable circumstances like grass-fire and volcanic eruption. Some old coconut-palms near Nagha on the east-coast showed a deep constriction in consequence of the eruption of Mt Awoe in 1892 and just below the crown a new constriction produced by the *Aspidiotus*-attack in 1927. The increase in length of the stem, 4 years after the *Aspidiotus*-outbreak, in 10 coconut-palms on the slopes behind Taroena was on an average 23 cm, i.e. 6 cm per year, while in healthy trees of the same age this increase (when growing under favourable conditions) is about 40 cm annually. In a vigorous young coconut-palm on the coastal plain the yearly increase in length after recovery was three times as large as during the *Aspidiotus*-attack.

The damage done by *Aspidiotus* was most pronounced in the weak palms growing on the steep slopes behind Taroena. About 50 per cent of these trees were killed ; even 3 years after the end of the outbreak the surviving trees had scarcily any fruits. In the deep erosion-gullies very few trees survived ; on the mountain-ribs between these gullies less trees ware killed. Of the vigorous coconut-palms on the coastal plain in and near Taroena about 30—40 per cent have died. Most fatal cases were found among full-grown and old palms ; young palms, though very liable to *Aspidiotus*-attack, showed more resistance, which is probably due to a better protection of the terminal bud by the erect leaves. As was already stated, nearly 400,000 palms were infested in the concluding stage of the outbreak of which about 30.000 were killed. It is intelligible that the ravages were greatest at Taroena where the outbreak lasted from the middle of 1925 till the close of 1927.

Serious outbreaks of *Aspidiotus destructor* have from time to time been reported from islands in the Indo-Pacific. Thousands of coconut-palms were killed by this scale-insect (and *Dactylopius cocotis* Mask.?) in the Laccadives about 1890 (Cotes 1896). Signoret (1869) states already that the coconut-trees in Rèunion were menaced with total destruction by *Aspidiotus destructor*. About 1900 there was an outbreak on the island of Yap (Carolines) in which 45 per cent of the

palms were killed (Preuss 1911); the copra-export, formerly 800 tons yearly, fell to nihil (Volkens 1901, Lindinger 1907 a). Mr. Janssen of Macassar, formerly director of the Jaluit Company, who visited Yap during the outbreak, told me that the dying coconut-palms exhibited the same symptoms as shown by my photographs from Sangi. According to Mr. Weller of Menado, who was from 1900—1919 coconut-planter in the Mariannes, most coconut-palms in Saipan and other islands of this group were killed by *Aspidiotus*-attack about 1912. In the Society-islands (Tahiti-group) *Aspidiotus destructor* did great damage since 1900; many coconut-palms were killed and many produced no fruits (Doane 1908). In more recent years outbreaks have been reported from Fiji (Taylor 1935) and Mauritius (d'Emmerez de Charmoy). It is remarkable that all these outbreaks occurred on smaller islands and that there are no reports about such ravages from the larger coconut-districts in Asia *).

Recovery of the coconut-palms began at Taroena, the original focus of the outbreak, and within half a year it spread over the whole infested area (see § 2). It was preceded by an abnormal mortality of the eggs and young larvae of *Aspidiotus*. The coconut-palms along the coast near Taroena put forth new green leaves (Dec. 1927). About one year later the withered leaves had almost disappeared on these trees. The recovery of the palms on the steep slopes was much slower. By the middle of 1929 withered leaves were still visible in these trees, but in April 1930, when I visited Sangi again, they had disappeared. The recovery was, however, still in progress. The new leaves in the centre of the crowns were much longer than the older leaves unfolded during and shortly after the attack (Pl. V, fig. 2). The umbrella-shape of the crown, seen during infestation, had changed into an ovoid one.

Three years after the end of the outbreak 90 per cent of the coconut-trees on the slopes were still without any fruits. Even five years afterwards soms trees still showed a marked difference in length between central and outer leaves showing that recovery was still in progress. From the best trees on the coastal plains the first fruits were picked about two years after the end of the outbreak.

The process of recovery may be illustrated by the case of one special coconut-palm near my temporary laboratory (in the govt. office) at Taroena. This tree, formerly a good bearer, had a very stunted crown at the end of 1927. The palm was examined and photographed 1, 2, 3, 4, and 5 years afterwards (Pl. VI). After one year the crown showed 12 small leaves, the central ones larger than the outer ones. After two years the leaves were much longer; 23 were counted. Flowers and fruits were still absent but soon afterwards some flower-spikes appeared. After three years 56 fruits were counted, 40 of which had already obtained their maximum size. The number of leaves was 29, the outer ones were still shorter than the central ones. Three months later 70 fruits were counted. After four years (Dec. 1931) 33 leaves and 73 fruits

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*) After my departure from the Dutch East Indies some new outbreaks of *Aspidiotus destructor rigidus* have occurred according to information received from Dr. L. G. E Kalshoven (Buitenzorg) and Dr. P. M. L. Tammes (Menado); I presume that like the Sangi-outbreak they were due to recent introduction of the insect.

In 1934 and 1935 there was a rather serious outbreak on the island of Bali in which about 15,000 coconut-palms were attacked (5000 severely and 10,000 moderately); the trees recovered after about two years. In 1934 there was also an outbreak on the island of Bawean (Java Sea). In 1937 a small focus was found near Menado (North Celebes), in which all infested leaves were cut. The Chalcidid parasite *Comperiella unifasciata* Ishii and the Coccinellid *Chilocorus politus* Muls. were introduced by the Institute of Plant-diseases into Bali as formerly into Sangi.

were present. The crown had assumed again its normal spheroid shape. After five years 37 leaves and 75 fruits were counted (Sept. 1932). The process of full recovery required four years in this case.

On the east-coast recovery showed the same course as at Taroena. About two years after the end of the outbreak the first nuts were picked from the best palms along the coast. In Bawonkoeloe (280 m above sea-level) I found two years after the outbreak 50 per cent of the coconut-trees still without flowers or fruits.

4. Systematic position and biology of the scale-insect.

a) Systematic position.

According to Ferris (1925) the classification of Coccidae is in a very unsatisfactory condition so that of about 2500 species described probably less than 1/5 can be identified from the literature with accuracy.

If one examines the literature on *Aspidiotus destructor* it appears that in this case too there is a great deal of confusion. The insect was shortly described by Signoret in 1869; his material came from Réunion. One sentence was devoted to the scale and one to the female. The figure of the pygidium shows very small median lobes as have never been found in any *destructor*-type from the Dutch East Indies. Material which I received from the adjacent island Mauritius is, however, identical with the typical *destructor* of the Malay Archipelago.

In 1896 Green described *Aspidiotus lataniae*, stating that it was identical with his former *Aspidiotus transparens* (Green 1890). In 1907 Green came to the conclusion that his description of *A. lataniae* (1896) refers to *A. destructor*. Finally in 1915 Green stated that the coconut-scale of Fiji was an intermediate form between *A. destructor* and *A. transparens* which are extreme types of one variable species. The same opinion is again expressed by Green in 1922, *A. transparens* Green is doubtfully distinct from *A. destructor* Sign. Lindinger (1907 b, 1909) called attention to the confusion of *A. destructor* and *A. transparens*. He published detailed figures of the pygidium of both species and described the features in which they are different. According to Lindinger Green's figures of *A. lataniae* (1896) refer to *A. transparens* and his description to *A. destructor*. Ramakrishna Ayyar (1919) is of opinion that only parts of Green's description of *A. lataniae* and *A. transparens* (in his work on the Coccidae of Ceylon) refer to *A. destructor*. Finally Chou Io (1938), working in the laboratory of Prof. F. Silvestri at Portici (Italy), published a re-description of *Aspidiotus destructor* Sign. His material was taken from banana-fruits in Italian Somaliland. He gives a detailed description and figures of the scale, the adult male and female and their larval stages. *Aspidiotus cocotis* Newst. (1893), *A. fallax* Cock. (1893), *A. transparens* Green (1890) and *A. stauntaniae* Takahashi (1933) are given as synonyms.

Aspidiotus collected from coconut-palms in Java, Celebes (with adjacent islands) and the Moluccas belong to two classes which are very different from a biological point of view. The first class, which contains several types (Pl. VIII, fig. 2, 3, 5), is apparently the *Aspidiotus destructor* Sign. of literature, which is found in all coconut-growing countries. The second class comprises only one uniform type which at present is only known from certain districts in Java and Celebes and probably also from the Pelew-islands. In a previous publication (Reyne 1947) it was described as a new subspecies of *Aspidiotus destructor* to which it is certainly closely allied. It was this very subspecies, called

rigidus, *) which caused the ravages on Sangi from 1925—1928. Though the typical *destructor* occurred in all villages outside the area infested by *rigidus*, it did neither increase nor cause the slightest damage. The outbreak of *rigidus*, starting from a few coconut-palms in Taroena, was almost certainly due to its recent introduction into that place.

When I arrived on Sangi (Aug. 1927) it struck me at once that the whole infested area was occupied by one homogeneous strain of *Aspidiotus destructor* with yellow males, while outside that area other types with red males were common. A detailed examination of females and males of the Taroena-type, including their larval stages, did not reveal any salient feature by which this could be separated from the other types. The pygidial structure of *rigidus* shows little variation, but some *destructor*-types have a similar pygidium (Pl. VIII, fig. 1—5). The cuticle, however, is very tough and elastic in *rigidus* at variance with the delicate cuticle found in typical *destructor*. Breeding experiments with *rigidus*, started at Taroena in 1928, proved convincingly that its biology differs considerably from that of the common *destructor*-type.

Differences between the subspecies *rigidus* and the typical *destructor* are as follows.

1) In *rigidus* the eggs are laid shortly before the emergence of the larvae, with legs, antennae, mouth-setae, and eyes completely developed. The eggs are deposited in small numbers (10—12 or less) near the pygidium, where the white egg-skins left after emergence of the larvae accumulate into a semi-lunar figure. In typical *destructor* the eggs are deposited in an early stage of development, usually before the reversion of the embryo. **) The whole space below the scale is filled up with eggs (commonly 40—60, sometimes 75—100) and after emergence of the larvae the white egg-skins lay scattered all around the body of the mother-insect. By this feature of mature colonies *rigidus* and *destructor* are easily recognised, even by the naked eye (Pl. VII).

2) The average duration of the life-cycle in the female of *rigidus* is 46 days (at sea-level) as against 32 days in typical *destructor* (Cf. tables below).

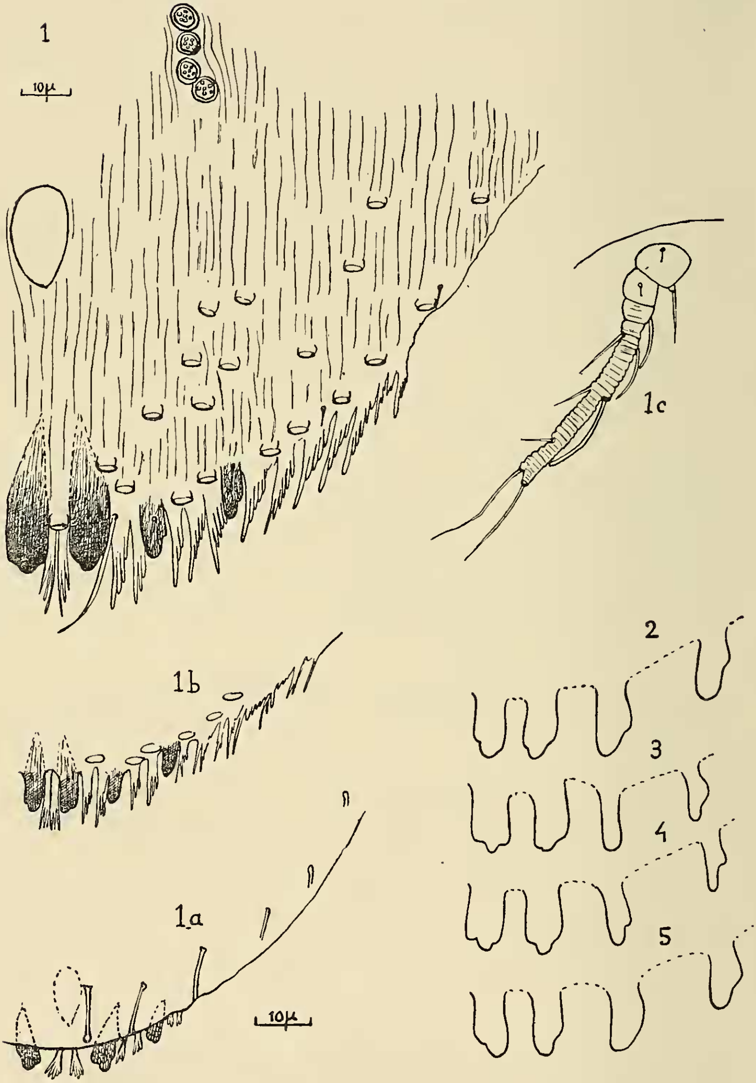
3) The mangosteen (Garcinia mangostana L.) is a favoured food-plant of *rigidus*, but not of typical *destructor*. Several strains of the latter, bred on mangosteen, died in the first or second larval stage without reaching maturity (Cf. section on food-plants).

From the view-point of economic entomology it is necessary to separate the subspecies *rigidus* from typical *destructor*, as all damage done by *Aspidiotus destructor* in the Dutch East Indies since 1925 is due to this subspecies (Sangi, North Celebes, Bali, Bawean). *Rigidus* and *destructor* have not the same natural enemies. The small Coccinellids *Telsimia nitida* Chap. and *Nephus luteus* Sicard often feed on common *destructor*, but not on *rigidus*, apparently because the cuticle is too tough to pierce with their mandibes. The Chalcidid parasite *Comperiella unifasciata* Ishii in the field only attacks *rigidus* (Cf. Reyne 1947). Parasite X (see § 5) often infests a high percentage of *destructor*-females, but in *rigidus* it was (with very few exceptions) only found

*) Mr. F. Laing (Br. Museum) identified the Taroena-type as *Aspidiotus destructor*. On calling his attention to the different biology and the tough cuticle, he proposed to name it var. *rigidus*, but did not publish this new name. Dr. H. Morrison (Bureau of Entomology, Washington) also identified the Taroena-type as *Aspidiotus destructor* Sign.

**) This applies to the first eggs deposited. When the space below the scale-covering is nearly filled up, more advanced stages are sometimes found within the body of the female.

PLATE VIII.



Explanation on p. 122—123.

in the males. These peculiarities are probably due to the longer duration of the life-cycle in *rigidus*.

A further description of the subspecies *rigidus*, which caused the Sangi-outbreak, is given below.

Scale 1.8—2.1 mm in diameter (height 0.17—0.22 mm), more or less smoke-coloured, fibrous, sometimes with an irregular outline, caused by one or more incisions. Exuviae of first and second larval stage measure 0.45 × 0.30 and 0.7 × 0.6 mm respectively. In typical *destructor* the the scale is generally more transparent, less fibrous, and sometimes provided with a faint radial striation, but in specimens collected in the Dutch East Indies never so pronounced as figured by Green for *Aspidiotus transparens* (Coccidae of Ceylon, vol. I, pl. 8; copy in Dammerman 1929). The scale-covering is very resistent against strong alkalis and acids (KOH, HCl, HNO_3, H_2SO_4). No differences were found between *rigidus* and *destructor* by the application of these and other reagents (as used for the detection of chitin, wax, silk, cellulose and albumins).

The median lobes of the pygidium in the subspecies *rigidus* are somewhat wider than the adjacent ones (Pl. VIII, figs 1 and 4), their length is equal or a little more than in the adjacent lobes. In *destructor* the median lobes are usually somewhat shorter and narrower than the adjacent ones (Pl. VIII, figs 2 and 5). In one type, however, which is found on Sangi as well as in Java, the median lobes are broader than the adjacent ones and of equal length (Pl. VIII, fig. 3). The fringed plates are alike in both types. In *rigidus* the anterior groups of circumgenital pores contain usually 8, the posterior groups 4 pores (total 24). *Destructor*-types show generally more variation in number and arrangement. No difference was found in the tubular spinnerets; there are about 20 of the larger type (macroducts) on each side. It seems that too much stress has been laid by different systematists on minute details in shape and size of the pygidial lobes. The *destructor*-types figured on plate VIII are identical with regard to their biology.

The female of *rigidus* has a pale green or greyish green colour; in *destructor* it is usually light green, sometimes yellowish green or yellowish and in one type orange, or rust-coloured. In most cases *destructor* has another colour than *rigidus*. The adult female of *rigidus* measures 1.15—1.25 × 0.9—1.0 × 0.16—0.22 mm; in typical *destructor* the females are sometimes smaller and more slender.

The males of *rigidus* are pale or bright yellow; their thoracic band (transverse apodema) is bright crimson. Some types of *destructor* have males like those of *rigidus* but in other cases they are red or rose, and sometimes of a golden or brownish yellow.

b) Distribution.

The subspecies *rigidus* is known to occur in the following districts:
1) West and Central Java. It is common around Buitenzorg; of 11707 *Aspidiotus*-leaflets, collected in 1929, 96,2 per cent contained *rigidus* and only 3.8 per cent typical *destructor*. In 1934 and 1935 there was an outbreak of *rigidus* on the adjacent island of Bali, which was probably due to recent introduction as it was on Sangi. It did also damage in 1934 on the island of Bawean in the Java Sea, according to Dr. L. G. E. Kalshoven.
2) South Celebes; in the town of Macassar and the country south of it, probably also along the the east-coast as far as Watampone.
3) The plain of Gorontalo and the north-coast of Celebes from Kwandang (north of Gorontalo) to the coconut-estate Biontong which lies more than 60 km eastward. On this coast damage by *Aspidiotus* was

first noticed at Boeko in 1920 according to the rajah of the district. I have seen an official report from 1925 by the district-officer in which it is stated that damage has been experienced since 1923, that the crop is reduced to 50 per cent, that the coconut-water becomes slightly sour, and that the pest is spreading in an eastern direction.
4) Island of Sangi (North Celebes). In 1927 the subspecies *rigidus* was still restricted to the infested area in the northern part of the island, but by the first months of 1930 it had spread all over Sangi.

In about 100 other localities, scattered over Celebes, and in the Moluccas (Halmahera, Amboina, Soela Islands, Batjan, Boeroe and Ombi), only typical *destructor* was found. The same applies to material, received from countries outside the Dutch East Indies, with the exception of a sample from the Pelew Islands (Pacific) which according to the arrangement of the egg-skins belongs to *rigidus*. Whether this subspecies occurs in Sumatra and Borneo is not known ; only three samples were examined from Sumatra and one from Borneo, which belonged to typical *destructor*.

Aspidiotus destructor rigidus on coconut-palms has a very discontinuous distribution in the Dutch East Indies, it occurs in the Pelew Islands, its parasite *Comperiella unifasciata* Ishii is at home in Japan. This leads to the supposition that the insect has been introduced into the Malay Archipelago from some East Asian country ; it is almost certainly an imported insect in the eastern part of the Archipelago. More data about the distribution of *rigidus* and its parasite *Comperiella unifasciata*, and about its food-plants, are needed before any definite statement on this point can be made.

c) Life-history and life-cycle.

The newly hatched larvae crawl about during 1—24 hours in search of a suitable place to attach themselves. Their length, width and height is about 0.22—0.23, 0.14—0.15 and 0.05 mm ; their speed when crawling on smooth writing-paper is from 13.0 to 26.6 mm per minute or 78—160 cm per hour. After fixation, which at least takes one hour, legs and antennae are withdrawn and minute white threads begin to appear on the upper side of the larva. By movements of the body, especially of the pygidium,these threads are matted together to a white cocoon which after impregnation by some fluid is transformed into a thin transparent scale. Berlese (1896) has shown that this fluid is secreted by the anus and that the pygidium acts as a spinning-apparatus. Metcalf and Hockenyos (1930) extracting Diaspine scales in bulk found 30—40 per cent of wax; the remainder (formed by the anal fluid ? *R*), which preserved the structure of the scale, was not identificable. The whole process of scale-formation in the young larva is generally completed within 24 hours.

Newly emerged larvae, if kept in glass vials, often bend their abdomen upwards and drop themselves. As even in a very dry atmosphere they remain alive during 1—3 hours, they can be easily transported by the wind in this way. In a moist atmosphere the crawling larvae live at least 1—2 days.

The first larval stage (larva I) is easily recognised by the presence of legs and antennae which are lost at the first moult. The cast skin of larva I is incorporated in the new scale of the second stage. In this stage (larva II) the difference between male and female becomes visible. The male is more slender than the female, its scale more spacious and elongate, and at the end of this stage the eye-pigment is clearly developed in the male. If the males are red, as in many *destructor*-types, the red colour soon begins to show itself in the second stage.

In this stage the male has still a pygidium like the female larva II, but it is lost in the third instar (prepupa), recognisable by 2 knobbed hairs at the tip of the abdomen. In the male prepupa the mouth-parts have disappeared, but initial antennae, legs and wings have developed. In the fourth stage of the male (pupa), recognisable by an initial genital stylus, the development to winged imago is completed.

The female moults only twice and the exuviae of both larva I and II are incorporated in the scale of the third stage. The male moults at least 3 times *) ; only the cast skin of larva I is incorporated in the scale, later exuviae are pushed out under the edge of the scale-covering. After the second moult the female comes already to maturity though it is, according to its structure and in comparison to the male, still in a larval stage.

Breeding experiments to determine the duration of the life-cycle of *Aspidiotus* were made on young coconut-palms in the field. Separate leaflets were enclosed in a sleeve-like bag of fine muslin, supported by 2 rattan-hoops ; the open ends were tied on one side to the leaf-stem and on the other side to a stick near the apex of the leaf (Pl. IX, fig. 3). The leaflets are not in the least damaged in this way. Breeding succeeds well in these muslin-bags, even in times of drought and heavy rains when infections with *Aspidiotus* in the open air often fail. The leaflets were infected with *Aspidiotus* by attaching heavily infested leaf-pieces, full of crawling larvae, to clean leaflets by means of paper-clips. After one day the attached leaf-pieces were discarded, the experiments were further examined daily. Individual insects were marked by ink-dots, but as a rule entire colonies of *Aspidiotus* were studied because of the high mortality in the younger stages. The duration of the first larval stage was determined by the time elapsed from the date of infection till the appearance of the first larvae II, the duration of the second larval stage by the time between the appearance of the first larvae II and the first larvae III. Breeding experiments were made at Taroena (Sangi) with *rigidus* and 5 different strains of *destructor* (Aug.—Nov. 1928) and at Buitenzorg (Java) with *rigidus* and 3 different strains of *destructor* (Dec. 1928—Febr. 1929). The material was collected in the neighbourhood of these places.

Table Ia. Breeding experiments at Taroena with typical destructor.
Number of days required to reach a certain stage of development, elapsed since the emergence of the larvae.

Stage		Average	Maximum	Minimum	Number of Observations
Larva II after ...... days		12.0	14	10	12
Larva III ♀ after ...... days **) .		21.3	23	20	13
First eggs deposited under scale after ...... days	4.4	25.7	28	23	11
First larvae emerged after ...... days	6.4	32.1	33	30	9
♂ Pupa after ...... days		18.9	19	17	4
♂ Imago after .... days		20.6	23	19	13
♂ Emerges from scale after ...... days		24.0	26	22	6

*) I have not noticed a moult between the prepupal and pupal stage, but may have overlooked it. Berlese (1896) states that it does not occur in any of the Diaspine scale-insects which he examined. Nel (1933), who carefully studied the metamorphosis of the male in *Chrysomphalus aurantii* (Mask.), observed a moulting of prepupa to pupa.

**) The mature female is called larva III ♀ in the tables.

Table Ib. Breeding experiments at Taroena with the subspecies rigidus.

Stage	Average	Maximum	Minimum	Number of Observations
Larva II after . . .. days	16.1	18	14	16
Larva III ♀ after ...... days . . .	30.1	32	28	15
First eggs deposited under scale after ...... days	11.9 } 42.0	44	40	9
First larvae emerged after .. ... days	3.9 } 45.9	50	44	9
♂ Pupa after ...... days	26.5	28	25	2
♂ Imago after . . . days	30.0	32	28	14
♂ Emerges from scale after ...... days	32.1	33	30	9

Table IIa. Breeding experiments at Buitenzorg with typical destructor. *)

Stage	Average	Maximum	Minimum	Number of Observations
Larva II after . .... days	13.3	15	12	16
Larva III ♀ after ... .. days . . .	23.1	25	21	12
First eggs deposited under scale after ...... days	5.3 } 28.4	31	26	16
First larvae emerged after ..... days	8.5 } 36.9	41	33	16
♂ Imago after ...... days	21.8	23	20	10
♂ Emerges from scale after .. ... days	22.8	24	22	4

*) In a breeding experiment, made in a greenhouse at Buitenzorg, in which a certain strain was reared during 10 generations, the emergence of the first larvae occured on an average after 34 days (maximum 38, minimum 32 days).

Table IIb. Breeding experiments at Buitenzorg with the subspecies rigidus.

Stage	Average	Maximum	Minimum	Number of Observations
Larva II after ...... days	17.8	20	17	11
Larva III ♀ after ..... days . . .	33.3	35	31	7
First eggs deposited under scale after ...... days	16.8 } 50.1	55	45	7
First larvae emerged after ...... days	3.6 } 53.7	58	49	7
♂ Imago after ...... days	31.8	35	29	5
♂ Emerges from scale after .. ... days	33.0	37	31	3

Table III. Average duration of development in days since the emergence of the larvae.

Stage	Subspec. *rigidus*				Typical *destructor*			
	Taroena		Buitenzorg		Taroena		Buitenzorg	
Larva II after .... days	16.1		17.8		12 0		13.3	
Larva III ♀ after ..... days	30.1		33.3		21.3		23.1	
First eggs deposited under scale after ..... days	42.0	11.9	50.1	16.8	25.7	4.4	28.4	5.3
First larvae emerged after ...... days (life-cycle ♀)	45.9	3.9	53 7	3.6	32.1	6.4	36.9	8.5
♂ Imago after ...... days	30.0		31.8		20.6		21.8	
♂ Emerged from scale after ...... days	32.1		33.0		24.0		22.8	
Life-cycle ♂*)	36 0		36.6		30 4		31.3	

*) To obtain the complete life-cycle of the male the incubation-period of the eggs (3.6—3.9 days in *rigidus*, 6.4—8.5 days in *destructor*) must be added to the figures of the preceding series.

The duration of development in *Aspidiotus destructor* Sign. and its subspecies *rigidus* is shown in tables I—III.

From table III it appears that the duration of development in *rigidus* as well as in typical *destructor* is somewhat longer at Buitenzorg (240 m above sea-level) than at Taroena (at sea-level). This is probably due to a difference of about 2.2° C in the average temperature at both places during the experiments. The difference in duration of life-cycle between common *destructor* (female 32.1—36.9, male 30.4—31.3 days) and *rigidus* (female 45.9—53.7, male 36.0—36.6 days) is clearly shown in table III. Further it appears from these figures that the development of the eggs in *rigidus* is largely passed within the mother-insect as compared with typical *destructor* (Cf. the figures behind braces).

Propagation is probably largely or wholly parthenogenetic. Though adult males are common and often seen among the females, copulation has never been observed in *Aspidiotus destructor* and its subspecies *rigidus*. In 3 *destructor*-colonies isolated by muslin-sleeves all males were killed in the second stage, while they were left alive in control-colonies with the same stock of *Aspidiotus*, but no appreciable difference was noticed neither in the number of larvae nor in the sex-ratio. The following observations seem to point to parthenogenesis. 1) Copulation was never observed. 2) Killing of all males in the second stage had no effect on the progeny. 3) In about 60 breeding experiments the subspecies *rigidus* and different types of typical *destructor* were breeding true. Even minute details were preserved in the succeeding generations, in the females as well as in the males. In *Aspidiotus destructor* and its subspecies *rigidus* parthenogenesis still waits cytological investigation (Cf. Schrader 1929).

The sex-ratio is variable (see table IV in this §), but in most cases 25—50 per cent of an *Aspidiotus*-colony consists of males. In vigorous batches the males are sometimes less numerous or almost absent. In other cases, especially on coconut-leaves exhausted by *Aspidiotus*-attack 90 per cent or more may consist of males. When infections are made with such leaves on a healthy and vigorous plant the normal sex-ratio is at once restored.

In the first months of 1926 when the outbreak at Taroena was at its height enormous swarms of winged males appeared; they were very troublesome to the inhabitants and covered everything, window-frames, furniture etc., with a thick layer of dust. During my stay on Sangi

(Aug.—Dec. 1927), when the outbreak came to an end at Taroena, these swarms were seldom seen. Only once I came across such a swarm near Taroena and found the itching of these insects very annoying on face and hands. In Febr. and March 1928, however, swarms of males were seen in the marginal zone of the infested area. On the north-coast of Celebes, where the attacks of *rigidus* are much milder than on Sangi in 1925—1928, swarms of males have not been noticed by the inhabitants.

In connection with what is said above I may refer also to the remarks of Taylor and Paine on parthenogenesis and sex-ratio in *Aspidiotus destructor* (Taylor 1935; pp. 5 and 12).

From the moment on which the first eggs hatch till 7—12 days afterwards many larvae emerge. Sometimes in *destructor* a few larvae still appear after 20 days and in *rigidus* after 30 days, but the emergence ceases before the next generation is mature. In the first days of emerging 6—8 larvae per day per female may hatch in typical *destructor* and 4—6 in *rigidus*.

The number of larvae which succeeds in fixation, when conditions are favourable, is generally 25—50, as shown in table IV, in which the sex-ratio is also indicated. Conditions are most favourable when a leaflet contains only a small number of *Aspidiotus* so that the newly born larvae can attach themselves in the immediate neighbourhood of the mother-insects; in this case they move seldom further than 10 cm. The area occupied by a young colony on a clean leaflet is usually not larger than 10 times the area of the mother-colony. During rapid multiplication, as observed in the Sangi-outbreak, a coconut-palm showing the first traces of *Aspidiotus*-attack was entirely covered by the scale-insects within half a year, in which about 4 generations of *rigidus* were developed. The rate of multiplication was from 5 to 10 times per generation under these circumstances.

Table IV. Number of larvae, produced by Aspidiotus destructor under favourable conditions (insects protected by muslin-bag, larvae spreading over one single leaflet).

Form of *Aspidiotus*	Number of Females	Number of progeny per female			Count made ...... days after emergence of first larvae
		Males	Females	Total	
Typical *destructor**) . . .	14	13	37	50	27
,, ,, . . .	10	14	30	44	23
,, ,, . . .	10	6	20	26	23
,, ,, . . .	8	24	26	50	23
,, ,, . . .	26	10	10	20	19
,, ,, . . .	10	13	51	64	27
,, ,, . . .	10	7	16	23	30
Subspecies *rigidus*	37	28	22	50	47
,, ,, . . .	45	17	23	40	53
,, ,, . . .	97	—	—	30	19
,, ,, . . .	3	—	—	27	18
,, ,, . . .	128	—	—	25	19
,, ,, . . .	3	—	—	36 **)	

*) For 3 isolated specimens the number of larvae was respectively 55, 46 and 50.
**) Calculated from the number in the third generation.

In the field, where the young larvae spread from tree to tree, the highest rate of multiplication in the *rigidus*-outbreak was only 2 times per generation, judged by the increase in number of infested trees during 1½ month. The average figure for the district Taboekan, where regular

counts of infested trees were made, was somewhat above 1.3 for the period 1 July—1 Dec. 1927 (about 2 for the period 1 July—1 Aug.). In the Taroena-outbreak the number of infested trees increased from c. 200 in Oct. '25 to 30.000 in Sept. '26, which indicates a rate of multiplication of about 2. In the Bali-outbreak (see § 3) the number of infested trees increased from about 600 in Oct. 1934 to about 15.000 in May 1935 (5000 badly attacked, 10.000 moderately) ; this indicates a rate of multiplication between 1.6 and 2.

As is intelligible many more larvae are lost in spreading from tree to tree than in spreading over a single leaf. Even in the latter case many larvae do not succeed in attaching themselves ; the sclerenchyma-bundles seem to be a serious obstacle. The larvae can only insert their setae in the tissue between these bundles so that they are often neatly arranged in rows. When the larvae are too much crowded (sometimes 80 per cm^2) many of them will perish and only 20—30 per cm^2 remain alive.

d) Influence of weather and climate.

Influence of different temperature on the duration of the life-cycle in *Aspidiotus* was already noticed in breeding experiments made at Taroena (sea-level) and at Buitenzorg (240 m above sea-level) ; in this case the average temperature showed a difference of about 2.2° C (Cf. table III). In an experiment which was especially made to investigate this point 10 similar coconut-seedlings were infected with typical *destructor* ; 5 of these plants were kept at Menado (sea-level) and 5 at Tomohon (720 m above sea-level). The average difference in temperature during this experiment was 4.5° C ; the average life-cycle of the female *Aspidiotus* was 31 days at Menado as against 42 days at Tomohon. The increase in duration of life-cycle was about 17 per cent in *rigidus* and 15 per cent in *destructor*, when the temperature fell 2.2° C (Taroena—Buitenzorg) and about 35 per cent in *destructor*, when the temperature was lowered 4.5° C (Menado-Tomohon).

It should be borne in mind that the temperatures mentioned above refer to the free air. The temperature of coconut-leaves in full sunlight is higher ; the blades of the leaflets may show 37—38° C and their midribs even 40—42° C. The maximum-, optimum- and minimum-temperature for the development of *Aspidiotus destructor* and its subspecies *rigidus* is not known ; breeding experiments with constant temperatures have not been made. The optimum-temperature will be rather high as the insect is only found in the tropics and as coconut-leaves in full sunlight often have a temperature of 36—37° C.

Rain. During heavy rains the rate of propagation is low, few larvae emerge, many adults die and the eggs under their scales too. Especially the typical *destructor* shows a high mortality during the rainy season ; on leaves which are wholly covered by these scale-insects often no living specimens remain. Artificial infections in the open air are difficult to make in this season, but in muslin-bags (pl. IX, fig 3) and in greenhouses infections succeed and the insects thrive well.

The eggs under the scales and newly born larvae seem to be most susceptible to unfavourable conditions like heavy rains and drought. Leaf-pieces full of crawling larvae were submerged in water during 1, 2, 4, 6...... 24 hours. A submergence of 4—6 hours had little effect, but further submergence destroyed the power of infection which was almost entirely lost when the leaf-pieces were kept during 24 hours under water. No difference was found in these experiments between *rigidus* and typical *destructor* though in the field *rigidus* generally stands rain better.

From observations in the field, especially from the regular collection of *Aspidiotus*-leaves to feed *Chilicorus politus* (see § 5) it appeared that *Aspidiotus* at Buitenzorg and on Sangi was most active during the driest months (Buitenzorg commonly June—Aug., Sangi Aug.—Oct.) when the rainfall was about 200—250 mm. As soon as the heavy rains began (Nov.—Dec.) there was a decline in multiplication. The same was reported from the north-coast of Celebes. In some cases a high mortality of eggs and young larvae was observed at the height of the dry season which was probably due to low relative humidity. In muslin-bags infections did succeed well, especially when the bags were kept wet during infection.

Sangi and the north-coast of Celebes, where the subspecies *rigidus* has caused considerable damage, have a similar rain-curve, but the activity of *rigidus* in this case may be due to recent invasion. Macassar and Gorontalo, where *rigidus* does no damage, have another type of rainfall than Taroena (Sangi) and Kwandang (North Celebes).

Aspidiotus destructor requires a high r e l a t i v e h u m i d i t y. The scale-insects are only found on the moist under-side of the leaf which contains the stomata and not on the dry upper-side which lacks them. Artificial infections on the upper-side succeed only when the atmosphere is kept very moist. As in the case of heavy rains the youngest stages, especially the eggs and mobile larvae, seem to be most susceptible to drought.

The distribution of *Aspidiotus destructor rigidus* in the field during the Sangi-outbreak showed clearly that it prefers a high relative humidity. It settled first in moist valleys. Four of such valleys were examined near Petta and two near Tola (see map Pl. I). In following the road from Petta southward I found Petta (at sea-level) heavily infested, the first hill-ridge (100 m) slightly infested, in the next valley a heavy infestation, on the following hill-ridge (110 m) very slight infestation ; after descending to Sensong (at sea-level) the trees were badly attacked, much worse than on the next hill-ridge (50 m). In the plain of Anggis on the west-coast *Aspidiotus* appeared first along the river-courses, but the dry, wide river-mouths (see § 2) were the last to be attacked.

In comparing temperature and relative humidity in moist deep valleys and adjacent hill-ridges on Sangi, differences were found of 1.3—3.5° C and 10—15 per cent of relative humidity ; the differences diminished at 10—11 a.m. and disappareared at noon. As *Aspidiotus* lives on the moist under-side of the leaf it is difficult to study the effect of dryness experimentally in the fixed stages. Breeding experiments in the open air compared with those in greenhouses and muslin-bags show, however, clearly that heavy rains and drought have a marked effect on the multiplication of these scale-insects.

The effect of w i n d in spreading *Aspidiotus destructor rigidus* was already described in § 2. High wind though favourable to the dispersal may be inimical to the development of *Aspidiotus* by its drying effect. P a i n e says that in Fiji there is generally a noted absence of wind in places where the scale-insects are abundant, that they are most prevalent in the wet zone, in close plantings, on low swampy soils and along valleys (T a y l o r 1935). On Sangi, however, the wind-swept coasts were heavily infested like the interior, but the hill-ridges less than the valleys between them, which is probably due to lower relative humidity, as they are more exposed to sun and wind. Young coconut-palms growing in the shade of old ones were often the first to be attacked.

e) F o o d - p l a n t s.

Numerous plants have been reported as food-plants of *Aspidiotus*

destructor. Several plants growing under badly attacked coconut-palms become infested by the young *Aspidiotus*-larvae which drop from the palms. In many cases, however, these larvae never reach maturity and die in the first or second larval stage which is often greatly protracted. Breeding experiments with typical *destructor* on mangosteen as described below may serve as an example. In my opinion only those plants are really food-plants on which *Aspidiotus* can live and breed continually.

During the Sangi-outbreak coconut-palms and banana-plants were badly attacked by the subspecies *rigidus* and mangosteen (Garcinia mangostana L.) too. The sago-palm (Metroxylon sp.) was only slightly attacked and remained green though there was a considerable reduction in crop (§ 2). Chrysalidocarpus lutescens Wendl., an ornamental palm found in many gardens in North Celebes, is often attacked by *rigidus*; of another ornamental palm, Cyrtostachys Renda Bl., specimens infested by *rigidus* were seen in Java as well as in Sangi; in Macassar I saw an ornamental palm with fan-shaped leaves (not identified) attacked by *rigidus*. Only once I found a small grove of nipah-palms (Nipa fruticans Wurmb.) on Sangi infested by *rigidus*.

Areca catechu L., Myristica fragrans Houtt., Mangifera indica L., Carica papaya L., and Hevea brasiliensis Müll. Arg. were not damaged by *rigidus* in the infested area on Sangi, though these trees are reported in literature as food-plants of *Aspidiotus destructor*. In artificial infections with typical *destructor* on betel-palms (Areca) and nutmeg-trees (Myristica) many larvae were alive after 14 days; 50 per cent had already died after 20 days and more than 90 per cent after 30 days; only a few larvae reached the second stage; after 60 days all were dead. In artificial infections on Carica papaya L., Mangifera indica L., Terminalia catappa L., Pandanus spec., Psidium guayava L. and Artocarpus integrifolia L. with typical *destructor* all larvae died in the first stage. In material collected on Yap in 1903, which I received through the kindness of Prof. Dr L. Reh (Hamburg), I found typical *destructor* (with egg-skins scattered all around the body) on leaves of Areca catechu and Carica papaya*); the latter plant is also heavily infested in Fiji (Taylor 1935, p. 8). Perhaps different strains of *Aspidiotus destructor* show a different behaviour against certain food-plants. Infections with common *destructor* on Eugenia moluccensis L. and Barringtonia sp. came to oviposition.

At Taroena artificial infections were made with the subspecies *rigidus* and 3 strains of typical *destructor* on the leaves of mangosteen (Garcinia mangostana L.). Only in one case 2 specimens of *destructor* reached the third larval stage, but they did not come to maturity. After 56 days these 2 female specimens were examined; only one of them contained 3 immature eggs, while the whole life-cycle on suitable food-plant occu-

After ...... days	*Rigidus*	*Destructor* strain I	*Destructor* strain II	*Destructor* strain III
10	69	83	9	35
15	69	31	1	4
20	69	23	0	0
25	66	13	0	0
30	59	5	0	0

*) After my departure Dr P. M. L. Tammes at Menado succeeded in breeding *destructor* to maturity on papaya-seedlings.

pies only about 32 days. In a second experiment *rigidus* was bred next to 3 different strains of *destructor*. The number of surviving larvae in *destructor* after 10, 15, 20, 25 and 30 days was as shown in the table on p. 105, below.

The duration of development in *rigidus* was in this case the same as in specimens living on coconut- or banana-leaves.

Similar results were obtained at Buitenzorg (Java). In 3 experiments with *rigidus* on mangosteen the colonies remained alive more than 130, 100 and 330 days respectively; the life-cycle was of normal duration. In the same experiment 2 strains of typical *destructor* died without coming to maturity. In the first case the number of surviving larvae after 10, 21, 31 and 40 days was respectively 168, 5, 2 and 0; after 31 days the larvae were still in the first stage which lasts only 12—15 days at Buitenzorg on suitable food-plants. In the second case the number of surviving larvae after 11, 17, 20, 25, 30, 39 and 49 days was respectively 212, 98, 78, 30, 17, 3, 0; only 4 larvae reached the second stage. In all cases reported the subspecies *rigidus* showed a normal development and a life-cycle similar to that on coconut-palms. From the above it is evident that mangosteen is a suitable food-plant for the subspecies *rigidus*, but not for typical *destructor*. In the field mangosteens infested by *rigidus* were found on Sangi, on the north-coast of Celebes (Boroko) and on Java (Buitenzorg).

Some other relations of *Aspidiotus destructor* to its environment may be mentioned (natural enemies are described in § 5). In collecting many thousands of leaflets in Celebes and the Moluccas for examining the degree of parasitism, I have always found that *Aspidiotus*-leaves can be easily collected in the villages and near the houses, while they are often scarce or absent elsewhere; the cause is not understood. Very conspicuous was this phenomenon in an undescribed Pseudococcid in the Talaud-islands (1927). The foliage of coconut-palms attacked by this scale-insect was wholly blackened by the presence of honeydew. The black palms began with the first house of a village and ended with the last house, they appeared again in entering the next village and disappeared after leaving it. In this case the visiting ants were perhaps associated with the houses. *Aspidiotus destructor*, however, secretes no honeydew and is not visited by ants. The *rigidus*-outbreak on Sangi started in the village Taroena but in spreading any preference for villages was not noticed.

A second phenomenon may be mentioned. When coconut-palms are only slightly infested *Aspidiotus destructor* is often associated with other scale-insects; sometimes 6 different species were present on one leaflet. In the Sangi-outbreak this was not observed; the smallest foci examined, containing 10—20 palms, were occupied by *rigidus* only. At the end of the outbreak, however, there was often a considerable admixture of typical *destructor*, *Chrysomphalus* and other scale-insects.

5. Natural enemies.

The numbers of injurious insects are often greatly influenced by weather-conditions (§ 4) and natural enemies.

Among the natural enemies of *Aspidiotus destructor rigidus* and typical *destructor* 3 species of fungi were observed. A red fungus (Aschersonia sp.) is widely spread in Java, Celebes, and the Moluccas, but its occurrence is not common; it was rather abundant in some moist valleys on Sangi. A black and a white fungus (not identified) were sometimes found on *Aspidiotus*. Possibly these fungi are largely saprophytic; as they are of little importance in the natural control of *Aspidiotus* no further attention was paid to them.

Insect enemies, parasites and predators, are of much greater importance than these fungi. The principal ones belong to the Chalcididae (Hymenoptera) and Coccinellidae (Coleoptera). In a few cases *Aspidiotus* was attacked by the ant *Monomorium destructor* Jerd., but this was only observed during breeding experiments in muslin-bags and not in the open air. *Aspidiotus*-colonies which showed a high mortality were occasionally infested by mites ; but it is doubtful whether they attack healthy, vigorous scale-insects.

On Sangi 3 species of Coccinellidae were found feeding on *Aspidiotus*, viz. *Telsimia nitida* Chap., *Nephus luteus* Sicard and *Chilocorus nigritus* Fabr.*). In the *rigidus*-area they were very scarce and not of the least importance as a natural check. According to breeding experiments these lady-birds and their larvae thrive well in colonies of typical *destructor*, but they are unable to feed on *rigidus* because of its tough cuticle.

Telsimia nitida (Chapin 1926) is a small black beetle with grey pubescence, measuring 1.7 mm × 1.2 mm. It is of common occurrence in colonies of typical *destructor* on the Sangi- and Talaud-islands and in North Celebes. In some cases more than 100 larvae of *Telsimia* were found on one single coconut-seedling. On Sangi it was very scarce in the infested area. All trials to feed these beetles on *rigidus*-colonies failed. Only in a few cases they succeeded in piercing the tough cuticle of a *rigidus*-specimen with their mandibles and in sucking out its body as they do with typical *destructor*. The same applies to *Platynaspis* sp., found near Buitenzorg (Java), and to the 2 following species of lady-birds.

Scymnus (Nephus) luteus Sicard is a yellowish, brown beetle, measuring 2.3—2.5 mm × 1.8—2.0 mm. It was sporadically found in the southern part of Sangi. This beetle feeds in the same manner as *Telsimia nitida*. One *Nephus*-larva can kill 20—30 adults of *Aspidiotus destructor* in a single day. In one experiment 8 larvae killed 637 adults of typical *destructor* in 4 days. On the 5th day these larvae were transferred to a vigorous *rigidus*-colony. Not a single scale-insect was killed ; the larvae left the leaf-pieces and died successively.

Chilocorus nigritus Fabr. is a shiny, bluish black beetle, measuring 3.4—3.6 mm × 3.3—3.6 mm. The larvae are not provided with white wax-tufts like the preceding ones, but with large spines. The beetle was rare on Sangi. It was also found on Siau (one of the Sangi-islands) in the Minahassa (North Celebes), and rather abundant around the town of Gorontalo (North Celebes). On Celebes it was also found at Madjene, at Bone (Dr P. van der Goot) and long ago in the town of Macassar (A. R. Wallace). According to Crotch (1874) it is distributed over Southern and East Asia (Br. India, Cochinchina, China, Japan). In experiments made at Taroena and at Gorontalo these beetles did not attack *rigidus*-colonies ; sometimes dead scale-insects were pulled into pieces and devoured. The larvae were also of little value as a check of *rigidus*. During 40 hours 12 larvae, confined in a glass jar, killed only 10 of 150 *rigidus*-specimens ; it took them more than one hour to pierce the scale and cuticle of one individual.

Afterwards some other Coccinellids preying on typical *destructor* were found in the Moluccas, viz. *Cryptolaemus affinis* Crotch, *Rodolia rubra* Muls., *Orcus* sp. and a few others (not identified). As far as my observations go, they are of little importance as enemies of *Aspidiotus*

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*) Identifications of these and other Coccinellids mentioned were made by Mr. G. E. Bryant (London). *Scymnus* (*Nephus*) *luteus* was described by A. Sicard (Ann. & Mag. Nat. Hist., series 10, vol. 3, 1929, p. 183).

destructor. *Chilocorus circumdatus* Schönh., found in North Celebes (Minahassa, Bolaang Mongondow, Gorontalo, Bwool, Bay of Dondo) but not in the *rigidus*-area between Kwandang and Biontong (see § 4), looked rather promising as in experiments one beetle killed about 100 *destructor*-specimens in one day. No experiments have been made with *rigidus*. This Coccinellid was rather numerous around the town of Gorontalo but only found on leaves with typical *destructor*. A small number of beetles was liberated in the *rigidus*-area between Kwandang and Biontong, but the species was not recovered (till 1933). According to Crotch (1874) and Schilder (1928) this insect occurs in Ceylon, Br. India, Sumatra and Hawai. The beetle is shiny, orange-coloured, with a dark border on the outher margin of the elytra ; measurements 5.0—5.3 mm × 5.0 mm. The larvae are pale orange-coloured and provided with spines. In the median dorsal rows are first 2 pairs of spines with a black base, then 2 pairs with an uncoloured base and further 5 pairs which have again a black base.

At the instigation of the late Dr P. van der Goot *Chilocorus politus* Muls. was introduced from Java into Sangi and North Celebes (Boroko) where *Aspidiotus destructor rigidus* caused considerable damage. According to Dr. van der Goot this Coccinellid is rather common in Kediri and other districts of East Java where it feeds principally on *Chrysomphalus*. In the laboratory, however, it could be easily bred when fed with *Aspidiotus destructor*. The beetle resembles *Chilocorus circumdatus* Schönh. but it is smaller and lacks the dark band on the outer margin of the elytra. The larvae of *politus* are readily distinguished from those of *circumdatus* as all spines have a black base. By the larval skins which remain upon the leaves, the presence of *Ch. politus* is easily recognised.

In July 1928 about 700 beetles were shipped from Buitenzorg (Java) to Taroena (Sangi), where some 400 arrived. The beetles were transported in large glass-jars, closed by cloth and packed in suitable cases ; during the voyage they were fed with *Aspidiotus*. Breeding was continued at Taroena with *Aspidiotus destructor rigidus* as food.

In August 1928 two colonies of 109 and 97 beetles were liberated at Sawang and Kalasoege on the north-coast of Sangi. When leaving Sangi in November 1928 100 larvae were released at Taroena ; all remaining leaf-pieces with eggs were tied on the leaves of young coconut-palms infested by *rigidus*. More than 400 beetles were taken to Boroko, lying in the centre of the *rigidus*-area on the north-coast of Celebes (about 40 km east of the harbour of Kwandang). Of these beetles 200 were liberated at Boroko and 200 at Nanoeka (14 km east of Boroko).

It was only in January 1930 that I could visit Boroko again. *Chilocorus politus* was well established at Boroko and Nanoeka. It was also found in Wakat between Boroko and Nanoeka and on the coconut-estates Bindjita and Biontong (11 and 14 km east of Nanoeka). On Biontong 40 beetles were captured within 2 hours.

In April 1930, when I visited Sangi, the beetle was recovered in two localities near Taroena, where the species had been released 16 months before. Further 53 leaf-samples were collected in different villages spread all over the island. In 7 of these samples (13 per cent) the cast skins of the larvae were found but living beetles and larvae only in one sample ; the introduced parasite *Comperiella unifasciata* Ishii was, however, represented in 92 per cent of these leaf samples.

One year later (2½ years after introduction) the beetles were still present at Taroena. On the coconut-estate Bindjita beetles and larvae were recovered 3½ years after the importation and in the neighbourhood of Boroko larval skins were found 4½ years after the liberation of the

beetles. *Chilocorus politus* seems to be well established in North Celebes, but as far as the observations go its effect on the *rigidus*-pest was still negligible in 1933.

The biology of this beetle was not studied in detail. From the daily breeding records kept by my native assistant S i m i n, who was charged with the multiplication of the beetles, the following data are derived for 5 newly born females, reared at Buitenzorg, and kept continually with males.

Female beetle	A	B	C	D	E	Average
Duration of life (in days)	121	115	147	90	112	117
Male added ...... days after emergence of female	13	18	15	14	15	15
Total number of larvae produced . .	303	154	208	149	250	213
Number of beetles reared from these larvae	55	49	56	34	53	49

The emergence of larvae in these 5 specimens lasted respectively 14, 14, 18, 10 and 13 weeks. Most larvae (40—50 per cent) emerged in the third and fourth week. The beetles were bred in glass dishes and young larvae were transferred with a camelshair-brush to fresh leaves. Probably the death-rate has been increased by these manupulations, so that under favourable conditions more larvae would have grown up to adult beetles.

From the breeding records kept at Taroena (sea-level), where *Chilocorus politus* was fed with *Aspidiotus destructor rigidus*, it appeared that the duration of the egg-stage was about 7 days, of the larval stage 13 days and of the pupal stage 7 days. At Buitenzorg (240 m above sea-level) the duration was somewhat longer; larval + pupal stage in the 5 specimens mentioned above lasted on an average 27 days (variation 25—30 days).

Three hymenopterous parasites (fam. Chalcididae) were found in the *rigidus*-area on Sangi, viz. *Spaniopterus crucifer* Gahan, *Aphytis chrysomphali* (Mercet) and a parasite, provisionally named parasite X by Dr. T a y l o r in 1926, which comprises 3 different species as appeared afterwards (see below). The first parasite belongs to the subfam. Encyrtinae, the two latter to the subfam. Aphelininae.

Spaniopterus crucifer was described by G a h a n (1928) after specimens collected by Dr. T a y l o r on Java in 1926. It is a brownish black parasite which can be easily recognised by a black X-shaped figure on the fore-wings. A detailed description and figures of fore-wing and antenna are given in G a h a n's publication. If imagines are absent confusion with another Encyrtine parasite, *Comperiella unifasciata* Ishii (introduced into Sangi) is possible, but the larval excrements at the sides of the pupa are formed by loose brown globules while in *Comperiella* they are a more or less compact orange-coloured mass. The larval stages and pupa are described in detail by T a y l o r (1935, pp. 34—36); development from egg to imago occupies 24 days on Java according to his observations.

It seems that this species is widely distributed in the Dutch East

Indies. Outside Java I have found it on Sangi in 15 of 59 villages examined (in 8.3 per cent of 217 leaf-samples). It was also found on other islands of the Sangi-group like Siau and Tagoelandang. It occurs on the main-island of Celebes in the district Minahassa (Menado, Toemaloentoeng, Marinsow), at Paleleh, Kolonedale, Bonthain and Macassar. It was found on the island of Halmahera (at Galela) and Morotai (at Wajoeboela). In Celebes (excepting Sangi) 170 leaf-samples were examined, *Spaniopterus* was found in 7 per cent of these samples.

As an enemy of *Aspidiotus*, *Spaniopterus* is of little importance as it occurs only locally and sporadically. In 6 among 30 cases examined the parasitism was 80—90 per cent, but in adjacent leaflets only 1 per cent or less. Typical *destructor* as well as the subspecies *rigidus* is attacked by this parasite.

Aphytis chrysomphali (Mercet) is widely spread in the tropics as a parasite of *Aspidiotus destructor* and other Diaspine scale-insects. It is easily recognised by its yellow colour and the typical arrangement of hairs on the fore-wings. It was found in several localities of the Sangi- and Talaud-islands and in many of North Celebes (Minahassa, Bolaang Mongondow, Gorontalo and environment, Bwool, Paleleh), also along the west-coast (Toli Toli, Sampaga, Bight of Tamboe, Donggala, Paloe, Mamoedjoe, Madjene, Pare Pare, Pangkadjene, Macassar, Bonthain) and on the east-coast of Celebes (Loewoek, Kolonedale, Sambioet). It was found in several localities of Halmahera, also on Ternate, Morotai, Batjan, Ombi, the Soela-islands, Boeroe and Amboina. It occurs in W. Java (Buitenzorg, Garoet, Wijnkoopsbaai), in C. Java (Klaten, Djember) and in E. Java (Banjoewangi). It was found in an *Aspidiotus*-sample from Bangka (Sumatra).

On Sangi *Aphytis* was observed in 85 per cent of the villages and in 51 per cent of the leaf-samples examined. From March—Aug. 1929 *Aspidiotus*-leaflets were collected from 578 localities around Buitenzorg (Java), in 59 per cent of which *Aphytis* was found. Of 22 leaf-samples with *rigidus*, collected in the plain of Gorontalo (Celebes), 64 per cent contained this parasite. It was found in 6 of 13 villages examined around Boroko (North Celebes).

Though *Aphytis* is widely spread in the Dutch East Indies, only a low percentage of *Aspidiotus* is attacked by it. In Buitenzorg (Java) the percentage varied from 1.5—2.6 (July—Dec. 1929). Only in 7 of 35 villages examined around Gorontalo and Boroko (North Celebes) the percentage was above 1 (maxima respectively 5 and 2.5).

On Sangi too the percentage of parasitism was low, seldom above 5 (in 14 of 217 leaf-samples). During the outbreak the parasitism in the *rigidus*-area was only about 0.1 per cent. A parasitism of 20—30 is sometimes observed, but only in small batches. Rather numerous was the parasite at Taroena during the decline of the outbreak (latter months of 1927, first months of 1928). In some places the parasitism had risen to 10 per cent and even more, but at that time in the remaining part of the *rigidus*-area the percentage was as low as before. In Sept. 1927 when the outbreak was still in full vigour a parasitism of 15 per cent was found at Lessa at the southern border of the infested area, but this had not slightest effect on the progress of the scale-insects as is intelligible (Cf. Reyne 1947).

Like *Spaniopterus*, *Aphytis* attacks *rigidus* as well as typical *destructor*; *Aphytis* attacks also male *Aspidiotus*, in *Spaniopterus* this has not been observed.

Aphytis is an external parasite, its larva lies under the scale-insect and sucks out its body. The larva is difficult to find but after pupation

the presence of the parasite is easily detected by the black elliptical larval excrements (arranged around the abdomen of the pupa) if the leaflet is held up to the light and examined with a hand-lens.

The imagines of *Aphytis*, in contrast with the other parasites of *Aspidiotus*, are in the habit of rushing rapidly over the *Aspidiotus*-leaves ; seldom more than 5 at a time are seen on one leaflet. The size of this parasite is very variable ; those from male *Aspidiotus* are much smaller than those from females. In some cases very large individuals were observed, presumably from other hosts than *Aspidiotus destructor*. The colour is also variable from citron yellow to yellowish brown and pale yellow.

The imago generally escapes below the edge of the scale but in some cases it bites an exit-hole. It was often observed that a female *Aphytis* pushed its ovipositor in dead scale-insects and even in the empty scales of *Aspidiotus*-males.

Breeding experiments to determine the life-cycle failed due to natural infection of the *Aspidiotus*-colonies, isolated by muslin-bags. In 2 cases *Aphytis* emerged from colonies of typical *destructor* which were respectively 22—27 and 21—26 days old. According to Taylor (1935, pp. 22—27) the development from oviposition to emergence takes only 12—15 days (egg-stage 3, larval stages 5—6, pupal stage 4—6 days). A description of the larval stages is found in Taylor's article. Among the specimens of *Aphytis chrysomphali* collected in the Sangi- and Talaud-islands 25—30 per cent of the adults were males ; at Buitenzorg this percentage was only 2.5.

Aspidiotiphagus citrinus Crawf. like *Aphytis chrysomphali* is a common parasite of Diaspine scale-insects, widely distributed in the tropics. Dr. Taylor called this parasite in 1926 provisionally parasite X. Gahan (1928) found that his parasite X comprised 2 species, *Aspidiotiphagus citrinus* Crawf. var. *agilior* Berl. and one which he described as *Casca parvipennis* n.sp. This *Casca* is very similar to the former, but the tarsi are 4-jointed, the antennae of the female 7-jointed and of the male 8-jointed as is easily recognised by microscopical examination. As in the parasite X of Sangi and North Celebes the number of tarsal and antennal joints is the same as in *Aspidiotiphagus citrinus* (respectively 5 and 8) I took it for this species. After my return from North Celebes I found upon closer examination that the shape of the forewings and the arrangement of hairs on them differed from *Aspidiotiphagus*. According to the Imp. Institute of Entomology in London this parasite X from North Celebes belongs to the genus *Prospaltella*. The species was probably *aurantii* How. (— Correspondence and material have been lost as my house was destroyed during the past war —).

As these identifications were made after the conclusion of the field-studies of Dr. Taylor and myself, I prefer to preserve the name parasite X in the present paper. Parasite X of *Aspidiotus destructor* around Buitenzorg (Java) is probably *Casca parvipennis* Gahan, and in Sangi and North Celebes *Prospaltella aurantii* How. It seems that *Aspidiotiphagus citrinus*, which has a wide range of hosts, attacks *Aspidiotus* occasionally in Java as well as in Sangi and North Celebes. The *Prospaltella* was found on Sangi (Kolongan, Metinta, Tola, Taroena, Tamako, Sawang, Petta and Lessa) and in North Celebes (at Tomohon and the coconut-estate Marinsow near Celebes' north point). *Aspidiotiphagus citrinus* was also present among my material from Sangi and North Celebes ; *Casca parvipennis* I have only found on Java. The confusion of the 3 species, all designated as parasite X, has no serious consequences in our case, since this parasite X (*Casca*, *Prospaltella* or *Aspidiotiphagus*) is not of the least importance as an enemy of *Aspidiotus destructor rigidus*.

Parasite X attacks males and females in typical *destructor*; in this species the parasite is very common. It is rare in *rigidus* in which, with few exceptions, I found only males attacked. This is evident from the following data. From 578 localities around Buitenzorg *rigidus*-leaflets were collected; parasite X was only found in 6 (1 per cent) of these samples. In leaflets with typical *destructor* from 95 localities it was present in 98 per cent of the samples. On Sangi among 169 *rigidus*-samples 32 (19 per cent) contained parasite X; the parasitism was generally below 1 per cent, only in one case 6 per cent. Of 47 samples with typical *destructor*, collected on Sangi, 42 (89 per cent) were attacked by parasite X. In 60 per cent of these samples the parasitism was above 20 per cent, in 36 per cent of the samples above 50 per cent; the average percentage was 35. In 87 localities of Celebes and the Moluccas typical *destructor* was collected. In 56 localities (64 per cent) parasite X was present; in 11 places the parasitism was 80 per cent or more.

From these figures it is clear that typical *destructor* is often heavily parasitised by parasite X. The occurrence is, however, very irregular. Often one can find next to *Aspidiotus*-colonies which are heavily parasitised batches of the same age which are not or only slightly attacked. Sometimes an old colony of *Aspidiotus* is badly attacked while the next generation (its progeny) is quite free from parasites. This very local parasitism was also observed in the other parasites and is probably due to lack of mobility in the parasites and to a preference for certain stages of *Aspidiotus* which may not be available in the neighbourhood when they emerge. In the agile *Aphytis* parasitism is generally more diffusely spread over the leaves.

When I arrived on Sangi it drew my attention that parasitism by parasite X was very low in the infested area (with *rigidus*) as compared with the villages outside that area (with typical *destructor*). Once 22 entire coconut-leaves wholly covered by typical *destructor*, heavily parasitised by parasite X, were fetched from Tamako and exposed in palms on the southern border of the infested area (near Tawoali), but this had not the slightest effect on the progress of *Aspidiotus destructor rigidus*. At Taroena I liberated many hundreds of parasite X on coconut-seedlings infested by female *rigidus* with the intention to spread the parasite by means of these seedlings, but the parasites refused to attack the scale-insects. The same experience was made with *Casca parvipennis* at Buitenzorg; 200 parasites were transferred to a *rigidus*-colony but refused to attack it.

The biology was not examined as the parasite was of no use against *Aspidiotus destructor rigidus*. In 2 experiments made at Buitenzorg on colonies of typical *destructor* (14—16 and 1—6 days old) the life-cycle was respectively 18—19 and 19—21 days; the pupae became visible after 13 and 15 days, i.e. 4—6 days before emergence of the imagines. On examining this material with the microscope it proved to be *Casca parvipennis*. In *Spaniopterus*, *Aphytis* and *Comperiella* the females of *Aspidiotus* are usually in the third stage when the parasites emerge, but in case of attack by parasite X (in typical *destructor*) they often fail to reach the third stage.

Besides the parasites mentioned a few others were observed in the *Aspidiotus*-samples which were collected from more than 1000 localities, distributed over 20 islands; most samples came from Sangi, Celebes and Java (Buitenzorg). No further attention has been paid to these parasites as they were of rare occurrence, except to *Comperiella unifasciata* Ishii which is a common parasite of *rigidus* around Buitenzorg. The biology of this insect and its introduction into Sangi and on the

north-coast of Celebes has been described in a previous paper (Reyne 1947). By its shiny black body and its wing-markings this parasite can be easily distinguished from *Spaniopterus crucifer*.

6. Causes of the outbreak. Means of control.

The causes of the rise and decline of the Sangi-outbreak are largely obscure like those of most other insect-pests. Especially in the case of *Aspidiotus destructor* and its subspecies *rigidus* it is difficult to give a satisfactory explanation as the outbreaks occur only occasionally and sporadically and as at present little is known of the biology and ecology of these insects. The *Aspidiotus*-outbreak was already in progress for more than 20 months and approaching its end when I arrived on Sangi. A survey of the status of parasitism in Sangi and North Celebes and the import and distribution of parasites from Java occupied all available time from Aug. 1927—March 1928 so that little attention could be paid to other subjects. Both subjects of this paragraph are, however, of such importance that a discussion is necessary.

Origin of the outbreak. The first question is, how could such a serious outbreak which, as far as records and remembrance go, has never occurred before in the Dutch East Indies, arise. Even the simple Sangirese had asked this question and found a solution to it which is worth mentioning. They thought that the "small yellow flies" (i.e. the males of *Aspidiotus*) originally lived in the soil, and that some drainage-work, carried out at Taroena for malaria-control, had driven them away from their original abode, after which they had taken refuge on the coconut-palms where they deposited their eggs (i.e. the female *Aspidiotus*). After some ingenious Chinese shopkeepers had been able to catch *Aspidiotus*-males in glass-bells put on the grass, all islanders seemed to believe that the theory had been experimentally proved.

Much has been written about the origin of insect-outbreaks, but a careful analysis of the factors involved is often lacking. Fluctuations in an insect-population may be due to several causes; Barber (1927) mentions no less than 25 limiting factors for *Pyrausta nubilalis* Hübn. which are constantly shifting in importance from season to season. Influences to which an insect-pest is subjected can generally be arranged in the following classes: 1) weather- and soil-conditions, 2) natural enemies, 3) food-supply, and 4) cultural and other measures taken by man.

In the temperate zone insect-life as well as plant-life is very dependent on weather-conditions as is even obvious to the layman. The influence of weather on insect-pests can be examined statistically in the field (census of insect-populations compared with records of weather and microclimate) and also by breeding experiments under controlled conditions of temperature and humidity in the laboratory (Cf. Uvarov 1931). Forecasting insect-outbreaks, based on previous weather-conditions, as in the case of *Porosagrotis orthogonia* Morr., is seldom possible (Cf. Cook 1928). The influence of weather on insects and their environment is usually too complicated to offer any definite base for forecasting outbreaks (Cf. Hinds 1928).

It is less obvious that even in the equable climate of the tropics weather-conditions are an important factor in determining the abundance of injurious insects. Rainfall is one of the most variable factors, by which tropical crops and insect-pests are influenced; a rain-gauge is found in every large plantation. As even the influence of rainfall on tropical crops and on the periodicity of tropical trees is often difficult to understand, it is no wonder that our present knowledge of the depen-

dance of tropical insect-pests on weather-conditions is still very meagre. Several injurious insects in the tropics show large fluctuations in numbers; of those affecting the coconut-palm in the Malay Archipelago we mention: *Aspidiotus destructor* Sign., *Locusta migratoria* L. var. *migratorioides* R. & F., some species of *Valanga* and *Sexava*, some Limacodidae, *Artona catoxantha* Hamps. and *Promecotheca cumingi* Baly. It is reasonable to suppose that in many cases weather-conditions play a part in determining the numbers of these insects. Van der Vecht (1936) has recently given a summary of what is known about the influence of weather-conditions upon insect-pests in the Dutch East Indies.

Next to weather-conditions natural enemies are often an important factor influencing the abundance of injurious insects. After some notable successes in California and Hawai with natural enemies imported (round about 1900) against introduced insect-pests, some entomologists had come to the conclusion that almost every insect-pest was due to scarcity or absence of natural enemies and had to be remedied by their introduction. Since 1900 the study of natural enemies and other environmental factors has made great progress and it has become evident that there are also several insect-pests in which natural enemies are a factor of minor importance. In consequence of this the enthousiasm for biological control has declined, especially in Europe, but also in America. Even Howard, the most prominent advocate of biological control in America, wrote in 1930: "I do not waver in my unfailing belief in the basic value of the principle of biological control, but my outlook becomes more or less confused when I consider the complications". Some remarkable results by the import of natural enemies have been obtained in isolated territories like islands*) and peninsulas, but very few in continental areas, including North America.

Advocates of biological control often fail to give statistical evidence for their alleged successes. The fact that a certain stage of an injurious insect is parasitised for 30 or 80 per cent has no meaning if the rate of reproduction in the host and if other factors of mortality are unknown (Cf. Sweetman 1935).

Food-supply is an important factor in some insect-pests in which natural enemies are of little importance, e.g. in *Oryctes rhinoceros* L. and *Stephanoderes hampei* Ferr. The food-supply of field-pests is dependent on weather-conditions and other factors, especially cultural measures. Cultural measures may change the effect of weather and climate (irrigation, shade-trees, cover-crops). Several cultural practices have a marked influence on injurious insects (planting-time, method of harvesting, variety planted etc.). The same applies to another human factor, viz. the involuntary introduction of an injurious insect into a new environment.

The principal factors influencing the numbers of injurious insects are represented in the following scheme:

Populations	← Natural enemies ↑		Cultural and
of injurious	← Weather- and soil-conditions	←	other measures
insects	↓ ← Food-supply		of man

*) Of 27 countries with successful cases, mentioned by H. L. Sweetman in his book: "The biological control of insects (Ithaca 1936)", 21 or 78 per cent are islands.

Besides these external or environmental factors there are sometimes internal factors, inherent in the insect, which play a part in its behaviour and fertility. They may be a consequence of external factors, e.g. when overcrowding or exhaustion of food-supply induces constitutional weakness resulting in high mortality or low fertility. In other cases these intrinsic factors influencing the density of populations are due to innate properties and a result of variation. The development of resistance against insecticides as shown by *Saissetia oleae* Bern. and other insects, and the existence of so-called biological races, prove that insect-species, which are identical from a morphological point of view, will not always respond in the same manner to a certain set of environmental conditions. Bodenheimer (1938) says with reference to the Red Scale (*Chrysomphalus aurantii* Mask.) examined by himself, and some insects studied by others, that "the physiological resistance and vitality of the same species towards the same combination of environmental factors is different in various generations and years" and (Cook 1930) "that a single species will react quite differently to its physical environment in different seasons". Physiological variation may play a part in the origin of insect-outbreaks. It is a well-known fact that some insects have changed their food-habits and adapted themselves to new food-plants.

If we ask which of the above-mentioned factors can have been responsible for the Sangi-outbreak, we have to state in the first place that the outbreak was probably due to recent importation of *Aspidiotus destructor rigidus* at Taroena, where it found favourable conditions for its development (densely planted coconut-palms all over the lower parts of the island, a humid climate, strong winds to spread it). On Sangi the infested area (with yellow and withered coconut-palms) was wholly occupied by the subspecies *rigidus* which was nowhere found outside this area. Typical *destructor* was common in all villages outside that area, but did not show the least signs of activity in contrast to *rigidus* (Aug.—Dec. 1927). The *rigidus*-pest, starting at Taroena (Sept.—Nov. 1925), had spread over the northern part of Sangi by the end of 1927, covering about ¼ of the island. Then the outbreak came to an end, first at Taroena, the original focus, and last in the marginal area. In the following two years *rigidus* spread in a very mild form over the remaining part of Sangi without causing complaints and without even being noticed by the inhabitants. Many imported plants and animals have become serious pests, e.g. water-plants like Elodea, Azolla and Eichhornia in Europe and Asia, some South American weeds in the Malay Archipelago and the Pacific, insects like *Aspidiotus perniciosus* Comst., *Icerya purchasi* Mask., *Lymantria dispar* L. and others in North America, *Stephanoderes hampei* Ferr. in the Dutch East Indies and Brazil, *Oryctes rhinoceros* L. in Samoa*). In some cases this is due to lack of natural enemies, ocurring in the home-country, but usually the causes of the virulence of such imported pests are obscure. It seems that a change of environment greatly increases the vitality, but after due time this vitality often decreases and may be reduced to normal or even negligible proportions as in the case of Elodea.

The fact that *Comperiella unifasciata* Ishii was not only absent in Sangi, but also in the second *rigidus*-area of North Celebes viz. the plain of Gorontalo, suggests that the insect there too was a recent introduction. This is almost certain in the case of the adjacent *rigidus*-area on the north-coast between Kwandang and Biontong, where *rigidus* was first

*) Several instances of imported plants and animals and their remarkable vigour and reproductive power are given by: G. M. Thomson — The naturalisation of animals and plants in New-Zealand, Cambridge 1922.

noticed in 1920 and causes considerable damage. The *rigidus*-area in South Celebes, West and Central Java with *Comperiella unifasciata* as a *parasite*, is probably of less recent date. As far as is known, outbreaks of *rigidus* have never been recorded from these districts since 1900. It is, however, possible that in these regions the insect was also imported from abroad (Cf. § 4). It seems that in Celebes harbours like Macassar, Gorontalo, and Taroena were centres of distribution.

Weather-conditions and food-supply were certainly not responsible for the Sangi-outbreak. There was no abnormal weather at Taroena in 1924 and 1925. The Taroena-caldera was already wholly planted with coconut-palms in 1885 (Hickson 1889). Typical *destructor* did not show the least increase in numbers under the same conditions of climate, food-supply and natural enemies. The Sangi-outbreak cannot be ascribed to a lack of parasites and predators as was originally done. Only the parasite *Comperiella unifasciata* did not occur on Sangi, but this was also the case in the plain of Gorontalo, where no *rigidus*-outbreaks are known since 1913. It is questionable whether the presence of *Comperiella unifasciata* could have prevented the Sangi-outbreak (Cf. Reyne 1947). A destruction of more than 90 per cent of the *Aspidiotus* would have been needed to prevent this epidemic.

It is quite certain that the decline and breakdown of the calamity within 1½—3 months (as shown by the succession of infested and non-infested coconut-leaves) was not due to the activity of parasites and predators. A drop in fertility and a high mortality among the younger stages of *Aspidiotus* was the direct cause of the end of the outbreak. I failed to find any disease in the scale-insects and ascribed the lack of fertility and the high mortality of the younger stages to a constitutional weakness, induced by exhaustion of their food-supply due to their own activity. Under outbreak-conditions as occurred on Sangi from 1925—1928 a coconut-leaf was exhausted and withered after having fed about 4 generations of *rigidus* i.e. within 6—7 months, sometimes even earlier. As the leaf becomes exhausted the scale-insect is under-nourished. I supposed that the effect accumulated and resulted in a rather sudden drop in the rate of multiplication, in this case after about 2 years, comprising some 16 generations of *rigidus*. To test this theory some experiments were started in which the same stock of *Aspidiotus destructor rigidus* was bred on clean coconut-leaves and on leaves exhausted by previous infestation by *Aspidiotus*. I expected a drop in fertility of the females and a preponderance of males on the exhausted leaves. By my transfer to Menado (where *rigidus* did not occur) and due to other work these experiments have not been continued. Experiments of this sort and others on the effect of rainfall, drought, transmittance from one food-plant to another, and research on the parthenogenesis, are needed to elucidate the biology of *Aspidiotus destructor* which is, as Taylor (1935) rightly observes, "one of these pests whose ravages are irregular and sporadic".

From the north-coast of Celebes it is reported that outbreaks of *rigidus* seldom last longer than 2 years. The outbreaks are much milder than that on Sangi which may be due to the fact that coconut-palms are only found in a narrow strip along the coast. From reports on outbreaks of *Aspidiotus destructor* in other countries it appears that the pest in one locality usually does not last longer than 2—3 years.

At present we know nothing about the causes of outbreaks of non-imported *Aspidiotus*. The causes of decline after mass-production are presumably the same in imported and non-imported *Aspidiotus* and dependent on crowding (over-population) to which sedentary insects like Coccids are very liable.

Measures of control. Very few methods of control are applicable in native coconut-cultivation as found on Sangi. Coconut-cultivation is always very extensive; even in well-managed European plantations $^2/_3$ of all labour is devoted to harvesting and preparing copra; one labourer has to care for 500 or more adult palms. Spraying of coconut-palms in native populations is out of question. The only method of control practicable under these circumstances is cutting away and burning the infested leaves. The natives will seldom carry out such measures of their own accord. They object to such measures as a coconut-palm whose leaves are cut away except 3—4 of the youngest ones will produce no crop during about 2 years; further they object to the treatment of trees which are newly attacked and not yet seriously damaged. In consequence of this it is generally necessary to make such measures compulsory by a decree of the government.

When the outbreak became alarming at Taroena the leaves of a few dozens of trees have been cut on instigation of the local government, but, as no favourable results were seen, the cutting was stopped. When the Director of Agriculture, Dr. A. A. L. Rutgers, visited Sangi in August 1927, he was struck by the sharp boundary line between infested and non-infested coconut-palms along the lower course of the river Maleboer (see Pl. I) which forms a tree-less barrier of about 50—100 m width (swept clean by previous volcanic mud-torrents). He proposed to prolong this barrier into the interior but on closer examination it appeared that several separate *Aspidiotus*-foci were already present in the plain of Anggis, one of them even more than 5 km beyond the Maleboer-river so that the project was not carried out.

The question is what results would have been obtained if the infested leaves had been cut in the initial stage of the outbreak (Oct.—Nov. 1925) when only a few hundreds of coconut-palms were attacked. I suppose that the area covered by the outbreak (— in this case comprising c. 400000 palms —) could have been considerably restricted. The best manner will probably be to cut the *Aspidiotus*-infested leaflets in the beginning stage when the scale-insects are still spreading over the tree and when no more than 10—30 leaflets per leaf are attacked. In a vigorous coconut-tree a leaf-area-reduction of not more than 10 per cent does not affect the crop.

Spraying with contact-insecticides was wholly beyond the reach of the native population by lack of apparatus and insecticides. Even in European plantations spraying of tall coconut-palms is difficult to perform and only practicable in small numbers of trees; young palms with a short stem offer no difficulties. No experiments in spraying against *Aspidiotus* have been made on Sangi. In Surinam I found that young coconut-palms of about 4 years, severely infested by *Aspidiotus destructor*, were killed outright by spraying with a 6 per cent emulsion of "carbolineum plantarum" which was used in a concentration of 8 per cent against scale-insects on Liberian coffee and Citrus-trees without appreciable damage to their foliage. The same experience was made in spraying young coconuts with kerosene-emulsion. If the emulsion was strong enough to kill the *Aspidiotus* the coconut-plants were severely damaged. It seems that in young coconut-palms these insecticides, running down the leaf-stalks, damage the tender tissues of the apical bud.

Biological control, in which no cooperation of the native population is wanted, is very desirable. In a few instances scale-insects have been successfully combated by the introduction of predators or parasites (*Icerya purchasi* Mask. — *Rodolia cardinalis* Muls. in California, *Aspidiotus destructor* Sign. — *Cryptognatha nodiceps* Mshll. in Fiji, *Diaspis pentagona* Targ. — *Prospaltella berlesei* How. in Italy). In other cases

as in *Aspidiotus perniciosus* Comst. and several Citrus-scales biological control was not successful so that it is still necessary to use insecticides.

Details on the introduction of *Comperiella unifasciata* Ishii from Java into Sangi and North Celebes and its establishment are given in my previous paper (1947). The importation of *Chilocorus politus* Muls. is described above in § 5. Up to 1933, when I left the Dutch East Indies, both insects had little or no effect on the abundance of *Aspidiotus destructor rigidus*, though they were well established. Taylor (1935) obtained no practical results with the introduction of parasites and predators from Java into Fiji and he doubts (like the present writer) whether the non-outbreak condition of *Aspidiotus destructor* on Java is only due to the presence of these natural enemies. The same applies, in my opinion, to *Aspidiotus destructor rigidus*. It was only after my departure from Asia that Taylor (1935) published the excellent results obtained by the introduction of the Coccinellid *Cryptognatha nodiceps* Mshll. from Trinidad into Fiji. If new outbreaks of *Aspidiotus destructor* and its subspecies *rigidus* might occur in the Dutch East Indies, it would certainly be advisable to import this Coccinellid from Fiji. Facilities for the introduction of natural enemies from far-away countries have been largely increased in recent time by air-transport. *Cryptognatha* was introduced into Fiji without its parasites which often prevent its useful effect in Trinidad. I once saw a serious outbreak of *Aspidiotus destructor* in a young coconut-planation near Paramaribo (Dutch Guiana) where these beetles*) became abundant only after all foliage had turned yellow so that they were of no avail.

We have to wait and see whether *Cryptognatha nodiceps* will eat *rigidus* with the same avidity as typical *destructor* and whether it will become naturalised in the Malay Archipelago as well as in Fiji. The results with the native *Chilocorus politus* Muls. and *Ch. circumdatus* Schönh., which are voracious feeders on *Aspidiotus destructor* in the laboratory, were rather disappointing in the field from some unknown cause. In general it is difficult to foretell the result of importation of natural enemies from abroad as we have always to reckon with some incalculable factors. It is, however, safe to accept that no harm can be done by the introduction of insect-enemies of Coccids as is possible with the import of birds or mammals against other animal pests.

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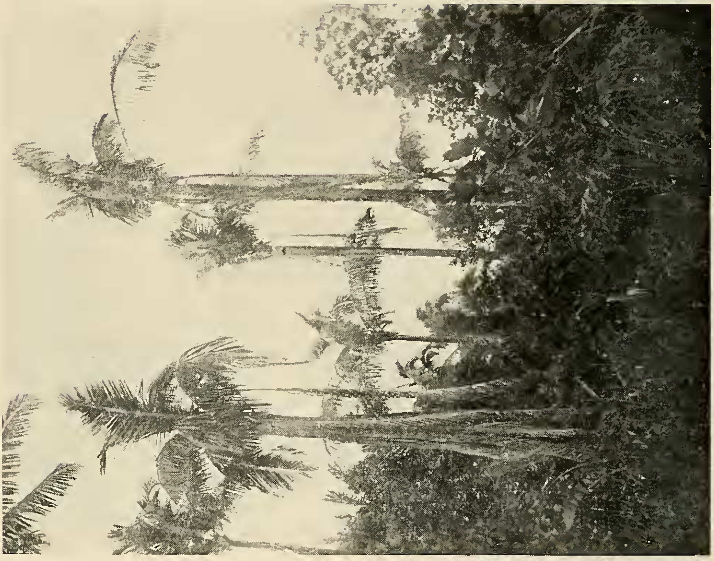
1

2

REYNE. OUTBREAK ASPIDIOTUS DESTRUCTOR RIGIDUS.



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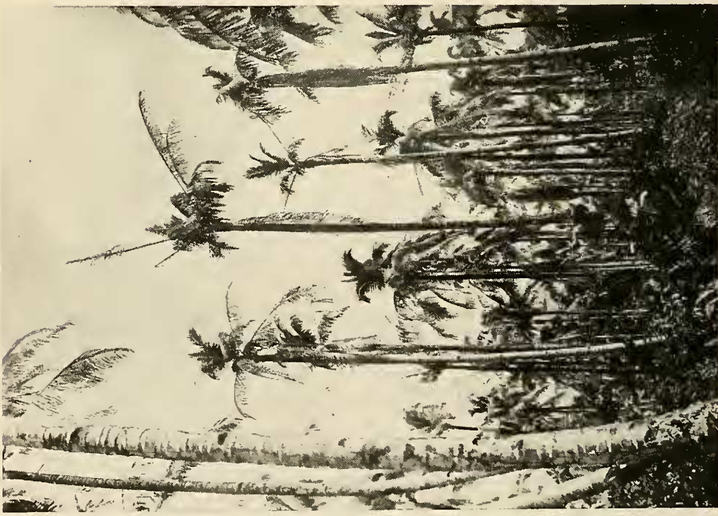

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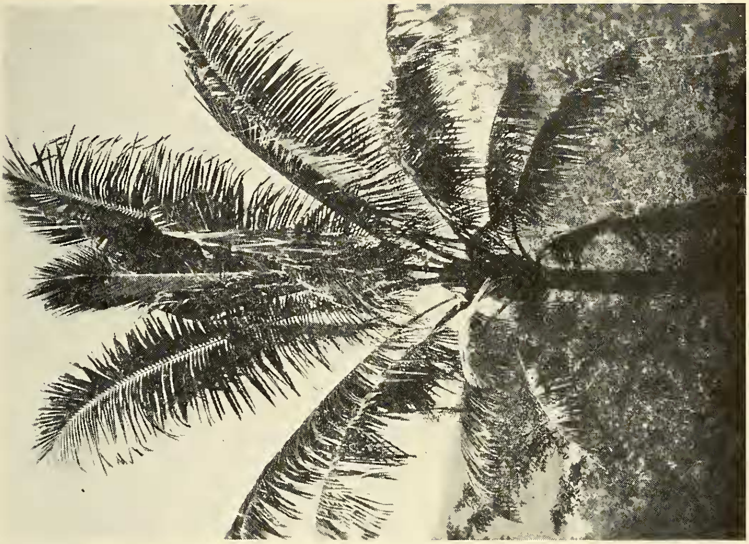
REYNE, OUTBREAK ASPIDIOTUS DESTRUCTOR RIGIDUS.



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REYNE, OUTBREAK ASPIDIOTUS DESTRUCTOR RIGIDUS.